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# SOIL

## *Bromacil and Diuron Residue Levels in Florida Citrus Soils*[1]

David P. H. Tucker[2]

ABSTRACT

*The widespread use of herbicides in Florida citrus groves raises the possibility of residue accumulation following repeated applications. To determine residue levels of commonly used herbicides, soil samples were taken from large experimental plots in commercial groves in Polk and Hardee Counties. Bromacil and diuron had been applied in combination at both locations for 7–8 years. Analyses of samples showed low levels of both herbicides at various soil depths to 60 cm. Only a small amount of bromacil was detectable one year after application, but diuron levels were higher. Continuous applications at recommended rates and frequencies have resulted in maximum bromacil and diuron levels of 3.9 percent and 13.1 percent, respectively, of their total application.*

### *Introduction*

Integrated weed control programs used on large acreages of citrus in Florida include herbicides, various cultivation practices, limited hand labor, and naturally occurring weed pathogens and insect pests. Herbicides have been widely used for the past decade, and have been applied annually to a large percentage of nonbearing and young-bearing acreage. Herbicides are now used on older groves to control rapidly increasing annual and perennial vines which thrive under tree canopies.

This widespread use of predominantly soil-sterilant herbicides has caused concern about their accumulation with repeated application. Therefore, continued monitoring of their residual levels in major citrus-growing soil types is warranted.

Bromacil and diuron are degraded in the soil by biological and nonbiological means, and they may be altered by one or more mechanisms including microbial decomposition, adsorption, volatilization, leaching, chemical degradation, and plant uptake (*2*, *5*, *7*, *8*). A number of review papers on this general subject have been presented (*3*, *4*). The persistence of soluble herbicides in soils in forms toxic to plants is likely to be less serious in humid areas such as Florida than in more arid citrus-growing regions. The amount, frequency, and intensity of rainfall is important to herbicide longevity in soil since moisture affects herbicide efficacy and mode of dissipation.

Tucker and Phillips (*9*) sampled the major citrus-growing soil types which had received repeated applications of herbicides. Analyses of these samples for bromacil, terbacil, dichlobenil, and trifluralin showed a fairly predictable annual rate of dissipation from the top 45 cm of the soil profile. The results precluded the possibility of any substantial toxicity to citrus trees due to accumulation in the soils following repeated applications at recommended rates. The present paper presents additional data showing levels of bromacil and diuron following their commercial application to two soil types at two grove locations over 7–8 years. Residue levels are shown at different locations under the tree canopy and at various depths.

### *Sampling and Analysis*

In 1969 and 1970, paired 10-acre blocks of citrus were selected in commercial groves in Polk and Hardee Counties. Soil types were Astatula fine sand (95 percent sand, 0.42 percent organic matter, pH 7.8) and Mayakka fine sand (99 percent sand, 0.38 percent organic matter, pH 7.3), respectively. Annual rainfall at both locations averaged 114–127 cm. The Hardee County grove has a permanent overhead irrigation system with supplemental irrigation averaging 30–50 cm/year. The Polk County grove receives only occasional supplemental irrigation. At each site, weeds were controlled by tillage in one block and by broadcast

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herbicides in the other. Generally, weed control was satisfactory with one application of herbicide each year. However, in some years, herbicides were re-applied when weed growth resumed before the end of the season.

Herbicides were sprayed by a machine-mounted boom to the entire grove floor area rather than in strips down tree rows. Wettable powder formulations of bromacil (5-bromo-3-sec-butyl-6-methyluracil) and diuron [3-(3,4-dichlorophenyl)-1,1-dimethylurea] in tank mixes or as a chemically blended combination were used throughout the experimental period. Soil samples were collected with a 2.2-cm-ID soil tube from 0- to 15-cm and 15- to 30-cm depths at both locations except at one sampling time when samples were also taken from 30- to 45-cm and 45- to 60-cm depths. Each sample was a composite of 10 subsamples. Samples were taken in row middles between trees, at the drip line or tree canopy edge, and under the tree canopy. There were three separate sampling times in Polk County and two in Hardee County. Care was taken in obtaining the lower depth samples to avoid the top soil layers falling into the holes. To assure this, samples were taken during optimum soil moisture conditions. Samples were stored at $-10°F$ before shipment for residue analyses by the Dupont Company. Samples were analyzed for bromacil by the microcoulometric gas chromatographic method of Pease (*6*), and for diuron colorimetrically after chromatographic cleanup by the method of Dalton and Pease (*1*).

### *Results and Discussion*

The data in Table 1 show that concentrations of bromacil and diuron at depths sampled are very low in both locations compared to the total amounts applied over the 7–8-year experimental period. The levels, as percentages of the total amounts applied, range from 0.3 to 3.9 for bromacil and from 3.7 to 13.1 for diuron. As percentages of the last application only, they range from 2.5 to 31.0 for bromacil and 33.6 to 84.6 for diuron. This indicates that a substantial part of the residues remains from the latest application within one year of sampling.

Residues of diuron remained at considerably higher levels in the soil than did those of bromacil. This is influenced primarily by their relative water solubilities: 800 ppm for bromacil and 42 ppm for diuron. Residue levels do not appear to be influenced by the location of sampling. Since precipitation is greater on the tree drip line due to the umbrella effect of the tree canopy, leaching would also be greater, resulting in an earlier breakdown in weed control.

Other factors which may influence residue levels at various sampling locations include photodecomposition of diuron, probably greatest in the row middles due to the high light intensity. Under tree canopies, where sunlight breakdown and precipitation would be less, adsorption of herbicides by organic matter and breakdown by microorganisms would be greater. Another factor to consider is that spray coverage is frequently poorer in areas where tree canopies hinder equipment movement.

Inadequate spray coverage in the tree row also is frequently due to poor overlap of spray patterns. In most cases, bromacil was more evenly distributed throughout the profile depth sampled than was diuron where higher concentrations were consistently found in the surface layers. Again, this is a reflection of the much lower solubility of diuron and hence its slower movement through leaching. Overall residue levels of both herbicides were higher in the Mayakka fine sand of Hardee County than in the Astatula fine sand of Polk County.

Bromacil levels in control samples taken from cultivated plots are at or very close to the lower end of the detection limit of the test procedure. Such background levels are not unusual in analyses of soils for herbicide residues. The levels of diuron are, however, more finite, and an explanation of these levels in the nontreated soil sample is more difficult. Contamination of soil in the cultivated blocks may have occurred when sandy soils were blown in during the dry windy season or washed in during heavy rains. Equipment movement throughout the experimental areas may also account for some movement of herbicides in the surface soil. The fact that diuron remains in the surface of the soil profile for longer periods would allow for greater movement than bromacil which is more rapidly moved into the lower soil profile.

From the data presented, it is evident that bromacil and diuron levels are relatively low in the 0–60-cm layers of the soil types sampled. Since soil was not sampled below 60 cm, the extent of residue movement through leaching into the lower soil profile is unknown. However, the data suggest that residue levels do decrease with depth. Although soil samples were not collected yearly, the data indicate that the degree of accumulation would not lead to cumulative levels toxic to citrus at rates used in commercial practice. This statement is supported by the fact that the tree foliage has not exhibited phytotoxicity symptoms throughout the experimental period. Rather, residues are steadily dissipating through leaching and degradation.

TABLE 1. *Bromacil and diuron residue levels in two Florida soil types*

| Herbicide | Rate, kg/ha | Total Applied, kg/ha | Interval Between Last Application and Sampling, Months | Soil Type | Sample Location | Sample Depth, cm | Residue: Bromacil kg/ha–15 cm (ppm) | Residue: Diuron kg/ha–15 cm (ppm) | Residue, % of: Last Application[1] Bromacil | Last Application[1] Diuron | Total Application Bromacil | Total Application Diuron |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Location I—Polk County** | | | | | | | | | | | | |
| Bromacil + Diuron | 3.6 + 1.8 | 25.1 + 12.5 (5 years) | 11 | Astatula fine sand | Row middle | 0–15 | <0.09 (<0.04) | 2.90 ( 1.30) | | | | |
| | | | | | | 15–30 | <0.09 (<0.04) | 1.07 ( 0.48) | | | | |
| | | | | | Drip line | 0–15 | <0.09 (<0.04) | 1.70 ( 0.76) | | | | |
| | | | | | | 15–30 | <0.09 (<0.04) | 0.51 ( 0.23) | | | | |
| | | | | | Under canopy | 0–15 | 0.11 ( 0.05) | 1.16 ( 0.52) | 2.5 | 72.9 | 0.3 | 10.5 |
| | | | | | | 15–30 | 0.09 ( 0.04) | 0.54 ( 0.24) | | | | |
| Control | | | | | | 0–15 | <0.09 (<0.04) | 0.36 ( 0.16) | | | | |
| Bromacil + Diuron | 3.6 + 1.8 | 28.7 + 14.3 (6 years) | 1 | Astatula fine sand | Row middle | 0–15 | 0.36 ( 0.16) | 2.24 ( 1.00) | | | | |
| | | | | | | 15–30 | 0.20 ( 0.09) | 0.50 ( 0.22) | | | | |
| | | | | | Drip line | 0–15 | 1.28 ( 0.57) | 2.22 ( 1.00) | | | | |
| | | | | | | 15–30 | 0.72 ( 0.32) | 0.60 ( 0.27) | | | | |
| | | | | | Under canopy | 0–15 | 2.46 ( 1.10) | 2.91 ( 1.30) | 26.6 | 80.4 | 3.3 | 10.1 |
| | | | | | | 15–30 | 0.73 ( 0.33) | <0.22 (<0.10) | | | | |
| Control | | | | | | 0–15 | <0.09 (<0.04) | <0.22 (<0.10) | | | | |
| Bromacil + Diuron | 3.6 + 1.8 | 32.3 + 16.1 (7 years) | 10 | Astatula fine sand | Row middle | 0–15 | 0.11 ( 0.05) | 1.84 ( 0.82) | | | | |
| | | | | | | 15–30 | 0.90 ( 0.04) | 0.69 ( 0.31) | | | | |
| | | | | | | 30–45 | 0.07 ( 0.03) | 0.34 ( 0.15) | | | | |
| | | | | | | 45–60 | 0.15 ( 0.06) | 0.27 ( 0.12) | | | | |
| | | | | | Drip line | 0–15 | 0.07 ( 0.03) | 1.34 ( 0.60) | | | | |
| | | | | | | 15–30 | 0.04 ( 0.02) | 0.54 ( 0.24) | | | | |
| | | | | | | 30–45 | <0.04 (<0.02) | <0.22 (<0.10) | 4.4 | 33.6 | 0.5 | 3.7 |
| | | | | | | 45–60 | 0.04 ( 0.02) | <0.22 (<0.10) | | | | |
| | | | | | Under canopy | 0–15 | 0.18 ( 0.08) | 1.14 ( 0.51) | | | | |
| | | | | | | 15–30 | 0.16 ( 0.07) | <0.22 (<0.10) | | | | |
| | | | | | | 30–45 | 0.09 ( 0.04) | <0.22 (<0.10) | | | | |
| | | | | | | 45–60 | 0.07 ( 0.03) | <0.22 (<0.10) | | | | |
| Control | | | | | | 0–15 | 0.09 ( 0.04) | 0.69 ( 0.31) | | | | |
| **Location II—Hardee County** | | | | | | | | | | | | |
| Bromacil + Diuron | 3.6 + 1.8 | 28.6 + 11.6 (7 years) | 8 | Myakka fine sand | Row middle | 0–15 | 0.18 ( 0.08) | 3.36 ( 1.50) | | | | |
| | | | | | | 15–30 | 0.07 ( 0.03) | 0.52 ( 0.23) | | | | |
| | | | | | Drip line | 0–15 | 0.74 ( 0.33) | 2.69 ( 1.20) | | | | |
| | | | | | | 15–30 | 1.46 ( 0.65) | 0.38 ( 0.17) | 18.2 | 84.6 | 2.3 | 13.1 |
| | | | | | Under canopy | 0–15 | 0.63 ( 0.28) | 1.88 ( 0.84) | | | | |
| | | | | | | 15–30 | 0.37 ( 0.39) | 0.31 ( 0.14) | | | | |
| Control | | | | | | 0–15 | 0.07 ( 0.03) | 1.03 ( 0.46) | | | | |
| Bromacil + Diuron | 3.6 + 1.8 | 28.6 + 11.6 (7 years) | 12 | Myakka fine sand | Row Middle | 0–15 | 2.24 ( 1.00) | 2.69 ( 1.20) | | | | |
| | | | | | | 15–30 | 0.60 ( 0.27) | 0.29 ( 0.30) | | | | |
| | | | | | Drip line | 0–15 | 2.04 ( 0.91) | 2.69 ( 1.20) | | | | |
| | | | | | | 15–30 | 0.67 ( 0.30) | <0.22 (<0.10) | 31.0 | 71.4 | 3.9 | 11.0 |
| | | | | | Under canopy | 0–15 | 0.85 ( 0.38) | 1.61 ( 0.72) | | | | |
| | | | | | | 15–30 | 0.31 ( 0.14) | <0.22 (<0.10) | | | | |
| Control | | | | | | 0–15 | <0.04 (<0.02) | 0.65 ( 0.29) | | | | |

[1] Values represent an average of residue levels from all depths.

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# FISH, WILDLIFE, AND ESTUARIES

## *Residues of Pesticides and PCBs in Estuarine Fish, 1972–76—National Pesticide Monitoring Program*

Philip A. Butler [1] and Roy L. Schutzmann [2]

ABSTRACT

*This report summarizes 1524 analyses of juvenile fish collected semiannually in 144 estuaries nationwide from July 1972 through June 1976. Pooled samples of 25 whole fish were screened for 20 common pesticides and polychlorinated biphenyls (PCBs). The three most common residues, DDT, PCBs, and dieldrin, were found in 39, 22, and 5 percent of the samples, respectively. Data indicate that estuarine pollution levels continue to decline.*

### *Introduction*

The economic and aesthetic importance of estuaries prompts many investigations to determine the causes and effects of imbalances in these sensitive ecosystems. The most comprehensive program was the monthly surveillance in 1965–72 for pesticide pollution of molluscan populations (*4*). The nationwide study identified the widespread contamination of estuarine fauna with DDT and demonstrated that DDT levels had peaked and were declining.

The persistence of DDT and other synthetic organochlorines made it desirable to continue monitoring estuarine areas, but it was necessary to reduce the analytical workload of the monitoring program. Unfortunately, residue data from molluscan populations are best understood when obtained continually. The animals purge themselves rapidly when pollution loading is intermittent (*3*).

The literature on accumulation and long storage of synthetic compounds by fish indicated that fish could be sampled less frequently than mollusks. However, little information was available on the sensitivity or selectivity of different species of fish in acquiring residues of specific pollutants or combinations of pollutants. Also, it was difficult to determine when and where migratory species acquired residues.

### *Sample Selection and Collection*

Many species of estuary fish spend only their first year within a single estuary; other species may spend their lifetime in an estuary. Presumably, fish less than a year old would reflect pollution levels during the preceding few months at or near where they were caught. So, each estuary was monitored at 6-month intervals in the spring and fall.

The geographic extent of this program meant that comparisons of residues in different species would be questionable. Consequently, in a given estuary, the same two species of fish were collected for the duration of the program. The two species represented different food webs, e.g., a carnivore and a particle feeder. This manner of sampling made it possible to detect pollution trends over the 4-year period.

Fish were collected with trawls and beach seines in 144 primary and secondary estuaries in 19 coastal states, Puerto Rico, and the Virgin Islands. Monitoring in Alaska, Hawaii, and Mississippi was limited to one year, but in most areas, six to eight semiannual collections were made during five calendar years. The 154 species collected represent 52 of the 175 families of marine fishes of North America (*1*). Some species and estuaries were monitored only once to identify possible problem areas. More than 60 species were sampled at least three times, and 22 species were collected in the estuaries of three or more states (Tables 1, 2). About 38,000 fish were analyzed in groups which made up 1524 samples.

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[2] Ecological Monitoring Branch, Pesticides Monitoring Laboratory, U.S. Environmental Protection Agency, Bay St. Louis, MS 39529.

TABLE 1. *Summary of estuarine fish collections, July 1972–June 1976*

| Coastal Area | Number of Years Monitored | Number of Estuaries | Number of Fish Species | Number of Samples[1] |
|---|---|---|---|---|
| Alabama | 3 | 3 | 4 | 13 |
| Alaska | 1 | 8 | 17 | 37 |
| California | 4 | 7 | 17 | 82 |
| Connecticut | 4 | 4 | 3 | 39 |
| Delaware | 4 | 3 | 11 | 57 |
| Florida | 3 | 11 | 22 | 66 |
| Georgia[2] | 4 | 9 | 15 | 74 |
| Hawaii | 1 | 8 | 14 | 22 |
| Louisiana | 2 | 14 | 14 | 51 |
| Maryland | 4 | 8 | 8 | 140 |
| Mississippi | 1 | 4 | 6 | 21 |
| New York | 4 | 3 | 4 | 46 |
| North Carolina | 4 | 19 | 28 | 251 |
| Oregon | 3 | 5 | 13 | 178 |
| Puerto Rico[2] | 3 | 5 | 14 | 25 |
| Rhode Island | 4 | 1 | 2 | 32 |
| South Carolina[2] | 4 | 6 | 5 | 99 |
| Texas | 4 | 9 | 8 | 51 |
| Virginia | 3 | 3 | 5 | 55 |
| Virgin Islands[2] | 2 | 8 | 19 | 28 |
| Washington state | 4 | 6 | 3 | 157 |
| TOTAL | | 144 | 154[3] | 1524 |

[1] Each sample consisted of 25 fish less than one year old.
[2] Some monitoring data for 1972–74 have also been published for these four coastal areas (see literature references *11, 12*).
[3] Different species, some species were collected in more than one state.

### *Sample Preparation*

Earlier laboratory investigations indicated that analyses of 15 randomly selected fish would cover the range of individual variations in pesticide concentrations in experimentally exposed fish populations (*2*). In the present study, 50 yearling fish were collected semi-annually and analyzed in pools of 25 each. Whole fish samples were homogenized, and an aliquot was blended with a desiccant as described in the molluscan program (*4*). The prepared samples were shipped unrefrigerated to the Pesticides Monitoring Laboratory, U.S. Environmental Protection Agency, Bay St. Louis, Mississippi, for analysis.

### *Analytical Procedure*

Desiccated samples were shaken with acetonitrile for 4 hours, and partitioned and cleaned by the Mills method (*8*); methylene chloride and hexane were used to elute the Florisil column (*9*). The extract was analyzed by flame photometric detector before Florisil cleanup to avoid possible loss of organophosphorus compounds (*6*). Polychlorinated biphenyls (PCBs) were separated from other chlorinated compounds by the silicic acid method (*7*). Instrument parameters and operating conditions used for gas chromatographic analysis and confirmation are given in Table 3. Samples were routinely screened for residues of the synthetic compounds listed in Table 4. The recovery range for organochlorines was 75–85 percent, and for organophosphates, 85–95 percent.

### *Results and Discussion*

#### ΣDDT

DDT is persistent in sediments with high organic content; its presence long after its use has been terminated is not surprising. However, DDT residues found recently in fish a few months old are not so easily explained. Of the states and territories monitored, DDT was absent only from Alaska, Hawaii, and the Virgin Islands (87 samples). In 595 samples, 39 percent, DDT was detected at levels of 10+ μg/kg (Table 5). In many areas, DDT residues were consistently present in small amounts in fish only a few months old. However, these low levels probably are biologically insignificant. Some samples from California, Delaware, Florida, and New York had DDT residues in the 1000–4000-μg/kg range. DDT burdens this high could cause physiological stress and lessen reproductive capacity in fish populations (*5*). The larger residues surpass levels observed in oysters in the same estuaries in 1965–72 when DDT was still being used. The fact that the half-life of pesticide residues is much shorter in mollusks than in fish may explain this paradox.

Coastal areas are ranked in the order of frequency and magnitude of ΣDDT residues in Table 6. Not surprisingly, the 10 areas with the highest frequency of positive fish samples are essentially the same coastal areas which had the highest frequency of ΣDDT-positive molluscan samples during 1965–72. However, there was a 30 percent decline in the overall frequency of DDT-positive samples of fish compared to mollusks in the 13 states where both were monitored. This decline was not uniform; in Delaware, the frequency remained at 75 percent, and in Washington state it declined from 11 to 4 percent.

Examination of the percentage distribution of DDT and its metabolites, TDE and DDE, in residues indicates to some extent the movement of DDT in the estuarine environment in recent years (Table 7). There has been a well defined shift from the large proportion of DDT in 1972 to its absence from fish samples collected in 1976 and the concomitant increase in levels of DDE. Yet, there has been no significant change in the mean residues of ΣDDT present during the 4-year period (Table 8). This suggests that DDT is continually recycled in the food web since it occurs in juvenile fish, and, in moving along biological pathways, DDT is gradually metabolized to the more stable compound. More important, it indicates that DDT is no longer being introduced into the estuarine environment and that a pollutant can be controlled nationwide by enforcing legislation.

#### POLYCHLORINATED BIPHENYLS (PCBs)

PCBs were identified in 331 samples, 22 percent of the total analyzed. Residues were quantitated by comparison with standards of Aroclors 1242, 1254, and 1260. In the data tabulations, PCBs are reported as a single entity regardless of the standard used to quantitate them. Thus, residues consisting of more than one PCB are not fully identified, and reported data of the actual amounts may vary.

TABLE 2. *Geographic distribution of fish species collected three or more times, 1972–76*

| SPECIES[1] | SCIENTIFIC NAME | COASTAL AREA | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | AL | AK | CA | CT | DE | FL | GA | HI | LA | MD | MS | NY | NC | OR | PR | RI | SC | TX | VA | VI | WA |
| Alewife | (*Alosa pseudoharengus*) | | | | | X | | | | | X | | | X | | | | | | X | | |
| American shad | (*Alosa sapidissima*) | | | | | | | | | | | | | | X | | | | X | | | |
| Atlantic croaker | (*Micropogon undulatus*) | X | | | | | X | X | | X | X | | | X | | | | X | X | | | |
| Atlantic menhaden | (*Brevoortia tyrannus*) | | | | | X | | X | | | X | | | X | | | | | | | | |
| Atlantic needlefish | (*Strongylura marina*) | | | | | | X | | | | | | | | | | | | | | | |
| Atlantic silverside | (*Menidia menidia*) | | | | X | X | X | | | | | | X | X | | | | | | X | | |
| Bay anchovy | (*Anchoa mitchelli*) | X | | X | | X | X | X | | X | X | X | | X | | | | | X | X | | |
| Blackcheek tonguefish | (*Symphurus plagiusa*) | | | | | | | X | | | | X | | X | | | | | | | | |
| Blueback herring | (*Alosa aestivalis*) | | | | | | | | | | | | | X | | | | | | | | |
| Bluefish | (*Pomatomus saltatrix*) | | | | X | | | | | | | | | X | | | | | | | | |
| Blenny | (*Cirripectes variolus*) | | | | | | | | X | | | | | | | | | | | | | |
| Buffalo sculpin | (*Enophrys bison*) | | | | | | | | | | | | | | X | | | | | | | |
| California halibut | (*Paralichthys californicus*) | | | X | | | | | | | | | | | | | | | | | | |
| Capelin | (*Mallotus villosus*) | | X | | | | | | | | | | | | | | | | | | | |
| Cunner | (*Tautogolabrus adspersus*) | | | | X | | | | | | | | | | | | | | | | | |
| English sole | (*Parophrys vetulus*) | | | X | | | | | | | | | | | X | | | | | | | X |
| Eulachon | (*Thaleichthys pacificus*) | | X | | | | | | | | | | | | | | | | | | | |
| Flathead sole | (*Hippoglossoides ellasodon*) | | X | | | | | | | | | | | | | | | | | | | |
| Gafftopsail catfish | (*Bagre marinus*) | | | | | | | | | X | | | | | | | | | | | | |
| Gizzard shad | (*Dorosoma cepedianum*) | | | | | | | | | X | | | | X | | | | | | | | |
| Great barracuda | (*Sphyraena barracuda*) | | | | | | | | | | | | | | | X | | | | | X | |
| Gulf killifish | (*Fundulus grandis*) | | | | | | X | | | | | X | | | | | | | | | | |
| Gulf menhaden | (*Brevoortia patronus*) | | | | | | | | | X | | X | | | | | | | X | | | |
| Hogchoker | (*Trinectes maculatus*) | | | | | | | | | X | X | | | X | | | | | | | | |
| Iao | (*Pranesus insularum*) | | | | | | | | X | | | | | | | | | | | | | |
| Little skate | (*Raja erinacea*) | | | | | | | | | | | | | | | | X | | | | | |
| Lizardfish | (*Saurida gracilis*) | | | | | | | | X | | | | | | | | | | | | | |
| Longfin smelt | (*Spirinchus thaleichthys*) | | | X | | | | | | | | | | | X | | | | | | | |
| Longnose killifish | (*Fundulus similis*) | | | | | | X | | | | | | | | | | | | X | | | |
| Pacific halibut | (*Hippoglossus stenolepsis*) | | | X | | | | | | | | | | | | | | | | | | |
| Pacific herring | (*Clupea harengus pallasi*) | | X | | | | | | | | | | | | X | | | | | | | |
| Pacific sanddab | (*Citharichthys sordidus*) | | | X | | | | | | | | | | | | | | | | | | |
| Pacific sandlance | (*Ammodytes hexapterus*) | | X | | | | | | | | | | | | X | | | | | | | |
| Pacific staghorn sculpin | (*Leptocottus armatus*) | | | | | | | | | | | | | | X | | | | | | | X |
| Pacific tomcod | (*Microgadus proximus*) | | | | | | | | | | | | | | X | | | | | | | |
| Pinfish | (*Lagodon rhomboides*) | | | | | | X | | | | | | | X | | | | | X | | | |
| Queenfish | (*Seriphus politus*) | | | X | | | | | | | | | | | | | | | | | | |
| Queen triggerfish | (*Balistes vetula*) | | | | | | | | | | | | | | | | | | | | X | |
| Rockhind | (*Epinephelus adscensionis*) | | | | | | | | | | | | | | | | | | | | X | |
| Sand seatrout | (*Cynoscion arenarius*) | | | | | | | | | X | | | | X | | | | | | | | |
| Sand sole | (*Psettichthys melanostictus*) | | | | | | | | | | | | | | X | | | | | | | |
| Sea catfish | (*Arius felis*) | | | | | | | X | | X | | | | | | | | | | | | |
| Shiner perch | (*Cymatogaster aggregata*) | | | X | | | | | | | | | | | X | | | | | | | |
| Silver jenny | (*Eucinostomus gula*) | | | | | | X | | | | | | | | | X | | | X | | | |
| Silver perch | (*Bairdiella chrysura*) | | | | | | X | | | | | | | X | | | | X | | | | |
| Southern kingfish | (*Menticirrhus americanus*) | | | | | | X | X | | | | | | X | | | | | | | | |
| Speckled sanddab | (*Citharichthys stigmaeus*) | | | | | | | | | | | | | | X | | | | | | | |
| Spot | (*Leiostomus xanthurus*) | X | | | | X | X | X | | X | X | | | X | | | | X | | | | |
| Spotfin mojarra | (*Eucinostomus argenteus*) | | | | | | X | | | | | | | | | | | | | | | |
| Spotted sand bass | (*Paralabrax maculatofasciatus*) | | | X | | | | | | | | | | | | | | | | | | |
| Stardrum | (*Stellifer lanceolatus*) | | | | | | | X | | X | | | | X | | | | X | | | | |
| Starry flounder | (*Platichthys stellatus*) | | X | | | | | | | | | | | | X | | | | | | | X |
| Striped anchovy | (*Anchoa hepsetus*) | | | | | | | | | | | | | X | | | | | | | | |
| Striped bass | (*Morone saxatilis*) | | | X | | | | | | | X | | | | | | | | | X | | |
| Striped mullet | (*Mugil cephalus*) | X | | | | | X | | X | | | X | | X | | X | | | X | | X | |
| Thread herring | (*Opisthonema oglinum*) | | | | | | X | | | | | | | X | | | | | | | | |
| Tidewater silverside | (*Menidia beryllina*) | | | | | | X | | | | | | | | | | | | | | | |

TABLE 2 (cont'd.). *Geographic distribution of fish species collected three or more times, 1972–76*

| Species[1] | Scientific Name | Coastal Area | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | AL | AK | CA | CT | DE | FL | GA | HI | LA | MD | MS | NY | NC | OR | PR | RI | SC | TX | VA | VI | WA |
| Walleye pollock | (*Theragra chalcogramma*) | | X | | | | | | | | | | | | | | | | | | | |
| Weakfish | (*Cynoscion regalis*) | | | | | X | X | X | | | | | | | | | | X | X | | | |
| White croaker | (*Genyonemus lineatus*) | | | X | | | | | | | | | | X | | X | | | | | X | |
| White mullet | (*Mugil curema*) | | | | | | | | | | X | | | X | | | | | | X | | |
| White perch | (*Morone americana*) | | | | | X | | | | | | | | X | | | | | | | | |
| Windowpane flounder | (*Scophthalmus aquosus*) | | | | | X | | | | | | | | | | | | | | | | |
| Winter flounder | (*Pseudopleuronectes americanus*) | | | X | | X | | | | | | | X | | | | X | | | | | |
| Yellowfin sole | (*Limanda aspera*) | | X | | | | | | | | | | | | | | | | | | | |

[1] See Literature Cited, ref. *1*.

PCBs were not found in samples from Alaska and Mississippi. In 11 states, Puerto Rico, and the Virgin Islands, Aroclor 1254 was the only standard used. In the remaining six coastal areas, standards of Aroclors 1242 and 1260 were occasionally required as well for the quantitation of residues (Table 5). The annual incidence of PCB-positive samples is summarized in Table 8. Data indicate a gradual decline in both the maximum residues observed in most years and the average concentration of the PCB residues. The changes were expected in view of the general curtailment in production and use of the compounds. Their chemical persistence suggests, however, that they will continue to contaminate the environment for several years.

Only at one station each in Delaware and Washington state did PCB residues frequently exceed 1000 μg/kg. Such data do not indicate high PCB levels in the ambient water since residues are cumulative and fish may have had up to one year of exposure. However, controlled experiments show that PCB concentrations as low as 1.0 μg/kg are sufficient to cause fin rot and increased mortality in chronically exposed fish (*10*).

Coastal areas are ranked in order of the frequency and magnitude of PCB residues in estuarine fish (Table 9). These residues were found in 19 of the 21 areas monitored, but in only four states were they present in more than half the samples. In contrast, DDT residues were found in 18 areas and were present in more than half the samples from nine states. This indicates a much broader contamination of the environment with DDT than with PCBs.

The incidence of PCB residues in fish cannot be compared with the much lower frequency observed in mollusks in 1970–72. PCBs are an industrial pollutant and are not usually found where shellfish are harvested.

### DIELDRIN

Residues of dieldrin were detected in 74 samples, 5 percent of the total samples, ranging from 10 μg/kg to 145 μg/kg. Positive samples were collected in some of the estuaries of 12 states and the Virgin Islands (Table 10). About half the positive samples were collected in secondary estuaries in the Maryland section of Chesapeake Bay. Samples from this area contained dieldrin in 1972–74, but not in 1975. Dieldrin was found in a variety of fish species, but its presence had no apparent correlation with their different feeding patterns. In 1972–74, dieldrin was found in about 7 percent of the fish samples; but in 1975–76, less than 1 percent of the samples contained detectable levels (Table 8). During the 1965–72 monitoring of mollusks, dieldrin was found in 15 percent of the samples at levels approximately double those detected in the juvenile fish.

TABLE 3. *Operating parameters for analyzing estuarine fish for pesticide and PCB residues—1972–76*

| Detector | Column | Temperatures, °C | | | Carrier Gas, Flow Rate |
|---|---|---|---|---|---|
| | | Column | Detector | Injector | |
| Electron-capture | Glass, 1.8 m long × 4 mm ID, packed with 3 percent DC–200 on 80–100-mesh Supelcoport | 188 | 300 | 250 | Argon/methane 50 ml/minute |
| Electron-capture | Glass, 1.8 m long × 2 mm ID, packed with a mixture of 1.5 percent OV–17 and 1.95 percent OV–210 on 80–100-mesh Supelcoport | 193 | 200 | 230 | Nitrogen 30 ml/minute |
| Electron-capture | Glass, 1.8 m long × 2 mm ID, packed with 5 percent OV–210 on 80–100-mesh Supelcoport | 173 | 200 | 230 | Nitrogen 30 ml/minute |
| Flame photometric | Glass, 1.8 m long × 4 mm ID, packed with 3 percent OV–101 on 80–100-mesh Chromosorb W–HP | 177 | 184 | 230 | Nitrogen 50 ml/minute |

TABLE 4. *Compounds detected by gas chromatographic analysis of estuarine fish tissue—1972–76*[1]

| Organochlorine | Organophosphate |
|---|---|
| Aldrin | Azinphosmethyl |
| Chlordane | Carbophenothion |
| DDT | DEF |
| Dieldrin | Demeton |
| Endosulfan | Diazinon |
| Heptachlor | Ethion |
| Lindane | Malathion |
| Methoxychlor | Parathion |
| Mirex | Phorate |
| PCBs | |
| Toxaphene | |
| Trifluralin | |

NOTE: See appendix for chemical names of compounds.
[1] Lower detection limit is 10 μg/kg for all compounds except the following: endosulfan, 20 μg/kg; methoxychlor and ethion, 30 μg/kg; mirex, PCBs, toxaphene, carbophenothion, and DEF, 50 μg/kg.

### PESTICIDES OCCASIONALLY DETECTED

Despite the fact that all samples were routinely screened for 21 synthetic hydrocarbons and their oxygen analogs, few were detected. DDT and its metabolites, dieldrin, and PCBs were the most common residues. Only six other pesticides were found in measurable amounts (Table 11). These were detected in 48 samples or about 3 percent of the total. A majority of these residues occurred in fish from the upper end of Chesapeake Bay and along the Texas coast. The insecticide endrin and the herbicide Dacthal (DCPA) were also identified in fish from a heavily farmed area in the Texas Rio Grande river basin. This area was monitored monthly and the data will be presented in a separate publication.

### DATA INTERPRETATION

The data are organized on a seasonal and geographic basis, i.e., by state boundaries, in an effort to make the large group of heterogenous samples more manageable. Unfortunately, some details of localized pollution patterns are lost in the process. For example, data from only one river basin in Rhode Island can be compared with data from 3–19 river basins in other states. Or, as in Washington state, data from one polluted estuary were averaged with five other relatively clean areas in the state. In Table 9, the frequency of PCB residues is shown as 17 percent in Washington. Actually, all 27 samples from the Duamish River were contaminated, but none of the 128 samples from the other five estuaries contained PCB residues during the 4-year period.

PCB residue data from the Duamish River samples illustrate the importance of sampling continuity to determine localized pollution patterns and trends. The Pacific staghorn sculpin and English sole were both collected seven times in the 4-year period. Quantitation of the PCB residues required three different standards (Table 12). The residues were probably mixtures of two or more PCBs, but the data indicate both a shift in the kind of pollution and a decline in pollution levels.

There must always be some ambiguity in the comparison of residue data from different species in the absence of controlled experiments on their ability to accumulate pesticides. In the Duamish River samples, the consistently higher residue levels in English sole probably were due to a difference in age rather than in species. Sole populations sampled were usually about 6 months older than the sculpins.

Comparisons of residue data in a single fish species distributed over a wide geographic range permit valid judgments of regional pollution differences. The bay anchovy was the most widely distributed species in the present program. It was collected in 37 estuaries in the 11 states from Delaware to Texas over a 3-year period. Samples from three estuaries in Georgia and three in Louisiana contained no detectable DDT or PCBs. In contrast, 42 bay anchovy samples collected in Delaware and Chesapeak Bay during this 3-year period contained residues of DDT (10–467 μg/kg, mean 77) and PCBs (90–996 μg/kg, mean 340). On the basis of such data, it is possible to identify regional pollution patterns when juvenile fish of the same species are monitored periodically.

In general, residue data from all the estuaries in a single state were strongly skewed because only one or two estuaries were highly polluted. In Washington state, less

TABLE 5. *Residues of ΣDDT and PCBs in whole-body samples of juvenile estuarine fish, 1972–76*

| Coastal Area, Year | Number of Samples | Residues, μg/kg Wet Weight | | | | | |
|---|---|---|---|---|---|---|---|
| | | ΣDDT | | | PCBs | | |
| | | Number Positive | Maximum Residue | Geometric $\bar{X}$ of Positive Samples | Number Positive | Maximum Residue | Geometric $\bar{X}$ of Positive Samples |
| Alabama | | | | | | | |
| 1972 | 2 | 2 | 82 | 67 | 0 | | |
| 1973 | 2 | 1 | 17 | 17 | 0 | | |
| 1975 | 3 | 2 | 35 | 20 | 0 | | |
| 1976 | 6 | 4 | 49 | 35 | 3 | 174 | 163 |
| Alaska | | | | | | | |
| 1972 | 7 | 0 | | | | | |
| 1973 | 30 | 0 | | | 0 | | |
| | | | | | 0 | | |
| California | | | | | | | |
| 1972 | 6 | 4 | 213 | 69 | 0 | | |
| 1973 | 21 | 19 | 667 | 75 | 2 | 270 | 229 |
| 1974 | 17 | 15 | 1422 | 69 | 5 | 512 | 224 |
| 1975 | 18 | 15 | 1349 | 79 | 6 | 432 | 210 |
| 1976 | 20 | 18 | 2588 | 95 | 12 | 400 | 254 |
| Connecticut | | | | | | | |
| 1972 | 4 | 3 | 63 | 43 | 4 | 592 | 313 |
| 1973 | 7 | 1 | 68 | 68 | 7 | 678 | 321 |
| 1974 | 15 | 4 | 43 | 26 | 14 | 1065 | 406 |
| 1975 | 5 | 4 | 97 | 25 | 5 | 497 | 252 |
| 1976 | 8 | 0 | | | 4 | 289 | 172 |
| Delaware | | | | | | | |
| 1972 | 6 | 6 | 1425 | 220 | 4 | 4504 | 1469 |
| 1973 | 12 | 12 | 636 | 85 | 7 | 2671 | 802 |
| 1974 | 14 | 13 | 1194 | 109 | 6 | 823 | 258 |
| 1975 | 9 | 8 | 1146 | 181 | 8 | 1566 | 720 |
| 1976 | 16 | 4 | 1015 | 471 | 4 | 1258 | 649 |
| Florida | | | | | | | |
| 1972 | 25 | 8 | 170 | 25 | 0 | | |
| 1973 | 15 | 4 | 18 | 13 | 0 | | |
| 1974 | 19 | 17 | 1640 | 36 | 16 | 614 | 62 |
| 1975 | 7 | 5 | 23 | 21 | 1 | 104 | 104 |
| Georgia | | | | | | | |
| 1972 | 12 | 3 | 65 | 26 | 1 | 508 | 508 |
| 1973 | 17 | 2 | 14 | 13 | 0 | | |
| 1974 | 10 | 1 | 32 | 32 | 1 | 137 | 137 |
| 1975 | 18 | 1 | 16 | 16 | 0 | | |
| 1976 | 17 | 0 | | | 0 | | |
| Hawaii | | | | | | | |
| 1972 | 8 | 0 | | | | | |
| 1973 | 14 | 0 | | | 3 | 305 | 244 |
| | | | | | 0 | | |
| Louisiana | | | | | | | |
| 1975 | 24 | 5 | 108 | 52 | 1 | 256 | 256 |
| 1976 | 27 | 1 | 23 | 23 | 0 | | |
| Maryland | | | | | | | |
| 1972 | 22 | 14 | 184 | 55 | 14 | 788 | 351 |
| 1973 | 45 | 26 | 345 | 73 | 12 | 1046 | 318 |
| 1974 | 45 | 35 | 694 | 51 | 16 | 878 | 287 |
| 1975 | 28 | 6 | 714 | 251 | 9 | 940 | 267 |
| Mississippi | | | | | | | |
| 1972 | 5 | 4 | 16 | 14 | | | |
| 1973 | 16 | 2 | 159 | 135 | | | |
| New York | | | | | | | |
| 1972 | 6 | 3 | 174 | 71 | 5 | 310 | 231 |
| 1973 | 10 | 5 | 115 | 49 | 2 | 235 | 149 |
| 1974 | 12 | 10 | 106 | 34 | 10 | 301 | 165 |
| 1975 | 6 | 5 | 4082 | 188 | 2 | 694 | 471 |
| 1976 | 12 | 10 | 104 | 39 | 10 | 447 | 295 |
| North Carolina | | | | | | | |
| 1972 | 30 | 29 | 140 | 43 | 15 | 786 | 258 |
| 1973 | 80 | 34 | 357 | 39 | 1 | 120 | 120 |
| 1974 | 70 | 26 | 322 | 39 | 3 | 174 | 131 |
| 1975 | 41 | 18 | 78 | 24 | 1 | 173 | 173 |
| 1976 | 30 | 18 | 140 | 33 | 2 | 538 | 527 |
| Oregon | | | | | | | |
| 1973 | 77 | 21 | 125 | 29 | 4 | 277 | 130 |
| 1974 | 66 | 22 | 221 | 32 | 7 | 247 | 179 |
| 1975 | 35 | 3 | 12 | 11 | 6 | 288 | 236 |

(*Continued next page*)

TABLE 5 (cont'd.). *Residues of ΣDDT and PCBs in whole-body samples of juvenile estuarine fish, 1972–76*

| Coastal Area, Year | Number of Samples | Residues, µg/kg Wet Weight | | | | | |
|---|---|---|---|---|---|---|---|
| | | ΣDDT | | | PCBs | | |
| | | Number Positive | Maximum Residue | Geometric $\bar{X}$ of Positive Samples | Number Positive | Maximum Residue | Geometric $\bar{X}$ of Positive Samples |
| Puerto Rico | | | | | | | |
| 1972 | 4 | 2 | 157 | 100 | 2 | 201 | 181 |
| 1973 | 8 | 1 | 172 | 172 | 2 | 416 | 316 |
| 1974 | 4 | 0 | | | 4 | 579 | 238 |
| 1976 | 9 | 5 | 86 | 28 | 0 | | |
| Rhode Island | | | | | | | |
| 1972 | 4 | 0 | | | 4 | 477 | 451 |
| 1973 | 8 | 0 | | | 4 | 797 | 464 |
| 1974 | 8 | 5 | 78 | 24 | 8 | 524 | 231 |
| 1975 | 8 | 4 | 20 | 17 | 4 | 241 | 230 |
| 1976 | 4 | 0 | | | 4 | 356 | 275 |
| South Carolina | | | | | | | |
| 1972 | 12 | 7 | 60 | 29 | 1 | 182 | 182 |
| 1973 | 25 | 13 | 33 | 16 | 0 | | |
| 1974 | 21 | 6 | 29 | 19 | 0 | | |
| 1975 | 22 | 2 | 12 | 11 | 0 | | |
| 1976 | 19 | 0 | | | 0 | | |
| Texas | | | | | | | |
| 1972 | 7 | 5 | 52 | 38 | 3 | 267 | 136 |
| 1973 | 9 | 5 | 188 | 82 | 0 | | |
| 1974 | 11 | 8 | 223 | 65 | 4 | 240 | 95 |
| 1975 | 18 | 12 | 59 | 23 | 4 | 265 | 150 |
| 1976 | 6 | 4 | 70 | 37 | 1 | 157 | 157 |
| Virginia | | | | | | | |
| 1973 | 26 | 20 | 124 | 39 | 8 | 438 | 214 |
| 1974 | 11 | 10 | 60 | 39 | 8 | 456 | 254 |
| 1975 | 18 | 7 | 821 | 115 | 5 | 2549 | 850 |
| Virgin Islands | | | | | | | |
| 1972 | 6 | 0 | | | 3 | 166 | 142 |
| 1973 | 13 | 0 | | | 0 | | |
| 1974 | 9 | 0 | | | 2 | 809 | 615 |
| Washington state | | | | | | | |
| 1972 | 21 | 0 | | | 4 | 4903 | 2552 |
| 1973 | 48 | 1 | 25 | 25 | 8 | 3363 | 1577 |
| 1974 | 48 | 1 | 11 | 11 | 7 | 2028 | 1515 |
| 1975 | 24 | 0 | | | 4 | 2639 | 2057 |
| 1976 | 16 | 4 | 38 | 32 | 4 | 900 | 668 |

NOTE: Samples from Alaska contained no PCBs. Aroclor 1254 was used as the standard in all other coastal areas with the following occasional additions: Aroclor 1260: California, Connecticut, Delaware, Maryland, North Carolina, and Washington state; Aroclor 1242: Delaware, Maryland, North Carolina, and Washington state.

TABLE 6. *Frequency and average concentration of ΣDDT residues in juvenile estuarine fish by coastal area, 1972–76*

| Coastal Area | Frequency of Residues, % | Coastal Area | Average Concentration, µg/kg[1] |
|---|---|---|---|
| California | 87 | Delaware | 213 |
| Delaware | 75 | Maryland | 108 |
| New York | 72 | Puerto Rico | 100 |
| Alabama | 69 | California | 77 |
| Virginia | 67 | New York | 76 |
| Texas | 67 | Mississippi | 75 |
| Maryland | 58 | Virginia | 64 |
| Florida | 52 | Texas | 49 |
| North Carolina | 48 | Connecticut | 41 |
| Puerto Rico | 32 | Louisiana | 38 |
| Connecticut | 31 | North Carolina | 36 |
| Mississippi | 29 | Alabama | 35 |
| South Carolina | 29 | Florida | 24 |
| Rhode Island | 28 | Oregon | 24 |
| Oregon | 26 | Washington state | 23 |
| Louisiana | 12 | Georgia | 22 |
| Georgia | 10 | Rhode Island | 21 |
| Washington state | 4 | South Carolina | 19 |
| Alaska | 0 | | |
| Hawaii | 0 | | |
| Virgin Islands | 0 | | |

NOTE: Comparisons are limited in that the number of samples, number of sampling stations, period (years) of sampling, and species of fish differ for each coastal area.

[1] Arithmetic average of geometric means of positive samples in all collection years.

than 4 percent of the samples collected in 5 years contained measurable residues of DDT. The geometric means of the positive samples, along with the maximum residue detected and the number of positive samples, is the best summary of actual pollution levels. Conversely, the geometric means of the residue data from year to year in a given state were normally distributed, and the arithmetic means were used to compare pollution levels in different geographic areas (Tables 6, 8, 9). Plans are under way to store sample and analytical data in a computer data bank to provide more precise data analyses in studies of localized pollution problems.

TABLE 7. *Percentage distribution of metabolites in ΣDDT residues in juvenile estuarine fish by coastal area, 1972–76*

| Year | Number of Positive Samples | Distribution, % | | |
|---|---|---|---|---|
| | | DDT | TDE | DDE |
| 1972 | 90 | 23 | 37 | 40 |
| 1973 | 167 | 12 | 30 | 58 |
| 1974 | 173 | 5 | 36 | 59 |
| 1975 | 97 | 1 | 21 | 78 |
| 1976 | 68 | 0 | 14 | 86 |

TABLE 8. *Annual incidence of ΣDDT, PCB, and dieldrin residues in juvenile whole fish samples, 1972–76*

| Year | No. of Samples | Residues, µg/kg | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | DDT | | | PCBs | | | Dieldrin | | |
| | | % Positive | Maximum Residue | Average Residue[1] | % Positive | Maximum Residue | Average Residue[1] | % Positive | Maximum Residue | Geometric $\bar{X}$ |
| 1972 | 187 | 48 | 1425 | 62 | 34 | 4903 | 540 | 7 | 140 | 21 |
| 1973 | 483 | 34 | 667 | 58 | 12 | 3363 | 429 | 6 | 140 | 30 |
| 1974 | 380 | 46 | 1640 | 42 | 29 | 2028 | 320 | 8 | 145 | 12 |
| 1975 | 284 | 34 | 4082 | 69 | 20 | 2639 | 460 | 1 | 15 | 14 |
| 1976 | 190 | 36 | 2588 | 88 | 22 | 1258 | 351 | 0 | — | — |

[1] Arithmetic average of the geometric means of positive samples from each coastal area.

## *Conclusions*

Juvenile fish are satisfactory tools for gauging pesticide pollution trends in estuaries provided at least 25 individuals, 6–12 months old, of the same species are sampled annually at a specific location. Analyses of the same species of fish at different geographic locations permit valid comparisons of pollution levels.

Existing ΣDDT residues are the result of biotic recycling, and probably little, if any, DDT has been introduced recently into the estuarine systems monitored in this study.

The magnitude and frequency of biotic residues of DDT, dieldrin, endrin, and toxaphene declined substantially between 1965–70 and 1972–76.

Data from this study warrant annual monitoring of juvenile fish in the nation's estuaries.

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TABLE 9. *Frequency and average concentration of PCB residues in juvenile estuarine fish by coastal area, 1972–76*

| Coastal Area | Frequency of Residues, % | Coastal Area | Average Concentration, µg/kg[1] |
|---|---|---|---|
| Connecticut | 87 | Washington state | 1674 |
| Rhode Island | 75 | Delaware | 780 |
| New York | 63 | Virginia | 439 |
| Delaware | 51 | Virgin Islands | 379 |
| Virginia | 38 | Rhode Island | 330 |
| Maryland | 36 | Connecticut | 323 |
| Puerto Rico | 32 | Georgia | 323 |
| California | 31 | Maryland | 306 |
| Florida | 26 | New York | 262 |
| Texas | 24 | Louisiana | 256 |
| Alabama | 23 | Puerto Rico | 245 |
| Virgin Islands | 18 | Hawaii | 244 |
| Washington state | 17 | North Carolina | 242 |
| Hawaii | 14 | California | 229 |
| Oregon | 10 | Oregon | 182 |
| North Carolina | 9 | South Carolina | 182 |
| Georgia | 3 | Alabama | 163 |
| Louisiana | 2 | Texas | 135 |
| South Carolina | 1 | Florida | 83 |
| Alaska | 0 | | |
| Mississippi | 0 | | |

NOTE: Comparisons are limited in that the number of samples, number of sampling stations, periods (years) of sampling, and species of fish differ for each coastal area.

[1] Arithmetic average of geometric means of positive samples in all collection years.

TABLE 10. *Geographic incidence of dieldrin residues in juvenile estuarine fish, 1972–76*

| Coastal Area | Number of Samples | Number Positive | Mean Residue, µg/kg |
|---|---|---|---|
| California | 82 | 2 | 34 |
| Connecticut | 39 | 3 | 15 |
| Delaware | 57 | 2 | 59 |
| Florida | 66 | 12 | 10 |
| Georgia | 74 | 2 | 60 |
| Louisiana | 51 | 1 | 15 |
| Maryland | 140 | 35 | 30 |
| Mississippi | 21 | 2 | 17 |
| New York | 46 | 2 | 24 |
| North Carolina | 251 | 4 | 20 |
| Texas | 51 | 6 | 20 |
| Virginia | 55 | 2 | 10 |
| Virgin Islands | 28 | 1 | 10 |

TABLE 11. *Pesticide residues occasionally detected in juvenile estuarine fish, 1972–76*

| State | Chlordane | Heptachlor Epoxide | Toxaphene | Ethyl Parathion | Methyl Parathion | Carbophenothion | Ethion |
|---|---|---|---|---|---|---|---|
| Alabama | 1–13–133 | | | | | | |
| Connecticut | | | | 1–39–10 | | | |
| Hawaii | 6–22–290 | | | | | | |
| Louisiana | | | 1–51–504 | | | | |
| Maryland | 22–140–118 | 3–140–15 | | | | 2–140–109 | 19–140–169 |
| Mississippi | | | 2–21–388 | | | | |
| New York | 2–46–207 | | | | | | |
| North Carolina | | | | 1–251–12 | | | |
| Texas | | | 3–51–75 | 3–51–75 | 2–51–47 | 1–51–103 | 1–51–83 |

NOTE: Data in columns represent incidence, number of samples, and mean residue, μg/kg, respectively.

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TABLE 12. *Trends in PCB residues in English sole and Pacific staghorn sculpin, Duamish River, Washington state, fall 1972–spring 1976*

| Date | Fish Species | Most Similar Aroclor Standard[1] | | |
|---|---|---|---|---|
| | | 1254 | 1260 | 1242 |
| Fall 1972 | E | 3346 | | |
| | P | 2202 | | |
| Spring 1973 | E | 2111 | | |
| | P | 2065 | | |
| Fall 1973 | E | 1683 | | |
| | P | 1129 | | |
| Spring 1974 | E | | 1927 | |
| | P | | 1477 | |
| Fall 1974 | E | | 1733 | |
| | P | | 825[2] | |
| Spring 1975 | E | | 2541 | |
| | P | | 1832 | |
| Spring 1976 | E | | 888 | 1241 |
| | P | | 506 | 492 |

NOTE: E = English sole, P = Pacific staghorn sculpin.
[1]Data represent average of two sample pools of 25 fish each (wet weight, μg/kg).
[2]Only one sample.

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# *Residues of Organochlorine Insecticides and Polychlorinated Biphenyls in Fish from Lakes Huron and Superior, Canada—1968–76* [1]

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ABSTRACT

*Five species of fish from Lake Superior and 12 species from Lake Huron were analyzed for organochlorine pesticides and polychlorinated biphenyls (PCBs) between 1968 and 1975. Mean residues of ΣDDT peaked at 1.72 ppm and 7.60 ppm in lake trout* (Salvelinus namaycush) *from Lakes Superior and Huron, respectively. By 1975, the mean level of ΣDDT had decreased in lake trout and was highest in bloaters* (Coregonus hoyi) *from both lakes: 1.06 ppm and 1.87 ppm, respectively. Dieldrin levels in fish from Lake Superior changed little over the same period. However, in 1969–70, dieldrin levels in fish from Lake Huron exceeded the 0.3 ppm tolerance level set by Health and Welfare Canada or the Food and Drug Administration, U.S. Department of Health, Education, and Welfare in 5 percent of lake whitefish* (Coregonus clupeaformis) *and 10 percent of bloaters. By 1975, 50 percent of bloaters caught in Georgian Bay and North Channel had dieldrin levels above 0.3 ppm. PCB residues declined in lake trout and lake whitefish caught in Lake Superior between 1971 and 1975, but increased slightly in bloaters and white sucker* (Catostomus commersoni). *Mean PCB residues in bloaters caught in Lake Huron in 1969–71 and 1975–76, and splake* (Salvelinus fontinalis *and* S. namaycush) *and cisco* (Coregonus artedii) *caught in 1975 exceeded the 2 ppm tolerance level.*

## *Introduction*

The Great Lakes are surrounded by land that is highly developed for urban, industrial, agricultural, and recreational activities. Since outflow of the Great Lakes is limited, chemical discharges into the lakes are very persistent. For the past decade organochlorines have been identified as a serious contaminant in fish, resulting in long-range detrimental effects to private and commercial fishing.

Organochlorine insecticides and polychlorinated biphenyls (PCBs) have been identified in fish caught in Lakes Huron and Superior. Reinhert reported residues of 0.2–7.4 ppm ΣDDT and 0.01–0.05 ppm dieldrin in several species of fish caught in Lake Superior in 1967–68 *(7)*. Reinke et al. reported that two fish species caught in 1970 from the same lake had mean residues of 0.2 ppm and 1.3 ppm ΣDDT and 0.06 ppm dieldrin *(9)*. Four species, also caught in Lake Superior in 1974–75, cited by the Upper Great Lakes Reference Group, contained mean residues of 0.2–4.4 ppm ΣDDT and 0.01–0.15 ppm dieldrin *(11)*. Residues of chlordane, lindane, and PCBs were also reported in these four species.

Reinhert found mean residues of 0.8–6.9 ppm ΣDDT and 0.02–0.11 ppm dieldrin in nine species of fish from Lake Huron in 1967–68 *(7)*. Reinke et al. reported mean residues of 0.5–16.4 ppm ΣDDT and 0.01–0.31 ppm dieldrin in the same major fish species in Lake Huron in 1970 *(9)*. The Upper Great Lakes Reference Group cited considerably lower residues of ΣDDT in three fish species caught in 1974–75 *(11)*, but levels of dieldrin, lindane, chlordane, and PCBs were similar to those found in other studies.

Studies on the distribution of organochlorines in water, sediment, and seston in Lakes Superior and Huron reveal that these compounds are widespread in the Great Lakes ecosystem *(3)*. Miles and Harris reported that the Muskoka River discharged large amounts of ΣDDT to Georgian Bay *(6)*. Peak discharges of 5.4 kg/week occurred in May 1971, but the quantity declined rapidly from May to October, averaging 0.9 kg ΣDDT/week. Frank et al. found that fish in the Muskoka Lake–Muskoka River system contained some of the highest residue levels found in fish from inland lakes of Ontario *(2)*. Fourteen species had mean residues of 0.22–22.4 ppm ΣDDT; sediments in this lake–river system contained ΣDDT residues as high as 2.9 ppm.

The present study, begun in 1968, was originally intended to identify and measure organochlorine residues

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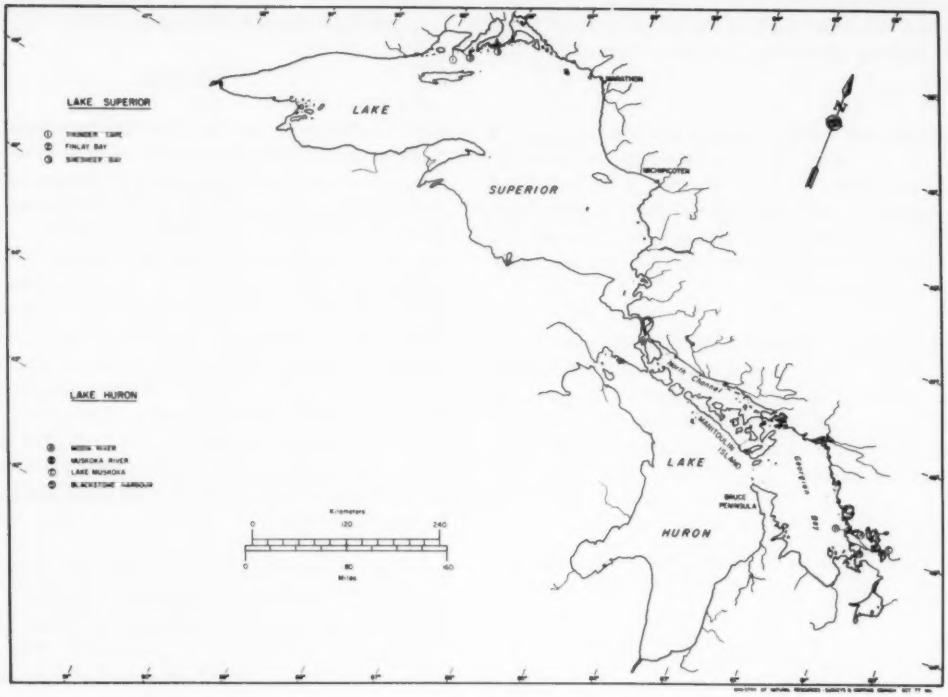


FIGURE 1. *Map of Lakes Huron and Superior showing fish collection areas*

in fish from the Great Lakes. However, it was broadened following restrictions on the use of aldrin, dieldrin, and heptachlor in Canada in 1969, DDT in 1970, and the voluntary restrictions on the use of PCBs in 1971 within the Province of Ontario. Authors wished to determine whether these use restrictions were significantly reflected in organochlorine residues in fish from Lakes Huron and Superior.

## *Methods and Materials*

### FIELD COLLECTION

Fifteen species (843 fish) were caught by net, line, or trap between 1968 and 1976 from Lakes Huron and Superior; many of the larger fish were obtained from commercial catches. Five species (115 fish) were caught in the Canadian waters of eastern Lake Superior between Michipicoten and the entrance to the North Channel (Figure 1). Between 1968 and 1976, 14 species (728 fish) were caught in Lake Huron. Of these, 481 fish of 12 species were from the Canadian waters of Lake Huron, 142 fish of five species were from Georgian Bay, and 105 fish of five species were from the North Channel. Bloaters *(Coregonus hoyi)*, coho salmon *(Oncorhynchus kisutch)*, and walleye *(Stizostedion vitreum vitreum)* were caught in southern Lake Huron, walleye caught in Georgian Bay at the mouth of the Moon River, and rainbow trout *(Salmo gairdneri)* and lake trout *(Salvelinus namaycush)* came from the south shore of Georgian Bay. Other species were caught between the Bruce Peninsula and Manitoulin Island.

Fish species were identified and named according to the nomenclature of the American Fisheries Society *(1)*.

### SAMPLE PREPARATION

Fish were measured, weighed, and where possible, the sex was determined. Heads and viscera were removed and the remainder of the fish was macerated in a Hobart meat grinder. A 150–200-g subsample was stored in a sealed glass jar at −20°C; storage time varied from a few days to four months. Individual fish were analyzed when the sample size was not limiting. Alewife, shiners, smelt, and other small fish were prepared as composites of similar sized fish. They were weighed and measured individually before being ground.

ANALYTICAL PROCEDURE

Ten grams of tissue homogenate was ground with 100 g anhydrous sodium sulfate and 25 g Ottawa sand. The mixture was extracted with 300 ml hexane for 7 hours in a Soxhlet extractor. Solvent was evaporated by rotary vacuum and the percentage fat was determined gravimetrically.

A one-step Florisil column cleanup method described by Langlois et al. *(5)* was used to isolate organochlorine insecticides and PCBs. A maximum of 1 g fat was mixed with conditioned Florisil and placed above another layer of Florisil. The column was eluted with a 300-ml 1:4 mixture of dichloromethane–hexane. Solvent was evaporated by rotary vacuum.

PCBs, Hexachlorobenzene (HCB), and organochlorine insecticides were separated on a charcoal column according to the method described by Holdrinet *(4)*. Analyses were performed with a Tracor Model 550 gas-liquid chromatograph (GLC). Instrument parameters and operating conditions follow.

| | |
|---|---|
| Detector: | $^{63}$Ni |
| Column: | 15 cm × 0.64 cm OD glass, packed with a mixture of 4 percent SE-30 and 6 percent QF-1 on 80–100-mesh Chromosorb W |
| Temperature: | 180°C |
| Carrier gas: | nitrogen flowing at 60 ml/minute |
| Injection volume: | 5 µl was equivalent to 1 ng fat sample |

Two-dimensional thin-layer chromatography was used on random samples for confirmation. Samples were removed, redissolved, and re-injected into the GLC column.

Recoveries were checked periodically by fortification of tissue homogenates prior to extraction. Average recoveries were:

| Residue | % | Residue | % |
|---|---|---|---|
| *o,p'*–DDT | 91 | Dieldrin | 89 |
| *p,p'*–DDT | 89 | *cis*-Chlordane | 98 |
| *p,p'*–TDE | 94 | *trans*-Chlordane | 90 |
| *p,p'*–DDE | 96 | PCBs | 85–90 |

The data were not corrected for recoveries. Detection limits were 0.005 ppm for organochlorines and 0.05 ppm for PCBs. PCBs were identified by comparing them with mixtures of Aroclors 1254 and 1260 and checking for a resemblance to peaks VII, VIII, and X on sample chromatograms according to Reynolds *(10)*.

Analysis was begun in 1968 when the known main contaminants in fish were *p,p'*-DDT and its analogs plus dieldrin and heptachlor epoxide; PCB values prior to 1970 were estimated. With the introduction of a column fractionation technique in 1970 for the separation of PCBs from organochlorine insecticides, the measurement of PCB residues became more precise. Analysis for HCB was included in 1973 but was discontinued because of the low level and incidence of HCB found in the samples. The analysis and confirmation for *cis*- and *trans*-chlordane was refined in 1975; analyses for mirex and oxychlordane were introduced in 1976.

## *Results*

LAKE SUPERIOR

*ΣDDT*—None of the five fish species caught in Lake Superior contained annual mean residues in excess of the 5 ppm tolerance level established by Health and Welfare Canada or the Food and Drug Administration, U.S. Department of Health, Education, and Welfare. The highest mean residue of 2.7 ppm was found in lake trout caught in 1968. However, of 18 lake trout analyzed, three contained residues of ΣDDT that exceeded 5 ppm (Table 1): a 1544-g fish caught in Shesheep Bay contained 14.1 ppm; a 2906-g fish caught off Thunder Cape contained 7.9 ppm; and a 3314-g fish caught in Finlay Bay contained 5.2 ppm (Figure 1). Lake trout caught in 1971 and bloaters caught in 1971 and 1975 contained the second highest mean ΣDDT residues of 1.16 ppm and 1.06 ppm, respectively, but no individuals exceeded the tolerance level.

Residues of ΣDDT declined in both lake trout and lake whitefish *(Coregonus clupeaformis)* between 1971 and 1975, but no trend was apparent in either bloater or white sucker *(Coregonus commersoni)*. The ratio of DDE plus TDE to ΣDDT increased in lake trout and lake whitefish from 1971 to 1975, indicating a metabolic breakdown of *o,p'*- and *p,p'*-DDT; this was not so apparent in bloaters and white sucker (Table 2). The decline is more evident in lake trout when similar weight classes are compared (Table 3). In spite of higher fat content in fish caught in 1975, ΣDDT is only a fraction of the residue found in 1968–70.

*Dieldrin*—No fish species contained mean residues that exceeded 0.08 ppm dieldrin, and no individual fish contained residues which exceeded the 0.3 ppm guideline set by FDA. The highest level of dieldrin found in an individual fish was 0.26 ppm in a lake trout caught in 1968. In general, levels of dieldrin were low, but the rate of disappearance of dieldrin since 1971 also has been slow. On the basis of a ΣDDT/dieldrin ratio, ΣDDT declined more rapidly than dieldrin between 1971 and 1975 (Table 2). Lake trout exhibited a decline in the ratio between 1968 and 1975 of 91 to 5. The ratio of PCBs to dieldrin changed little between 1971 and 1975. This was borne out when similar weight classes of lake trout were compared (Table 3).

*PCBs*—None of the five fish species caught in Lake Superior contained mean residues of PCBs greater than the 2 ppm tolerance level set by Health and Welfare Canada (Table 1). However, two individual trout caught

TABLE 1. *Organochlorine residues in five fish species caught in the Canadian waters of eastern Lake Superior, 1969–75*

| Species | Year | No. of Analyses | Mean and Range Weight, g | Mean and Range Fat, % | Mean Content and Range of Contaminants in Fish Puree, ppm[1,2] DDE | TDE | DDT | ΣDDT | Dieldrin | PCBs |
|---|---|---|---|---|---|---|---|---|---|---|
| *Catostomidae* | | | | | | | | | | |
| White sucker | 1971 | 5 | 1102 | 2.2 | 0.08 | 0.01 | 0.04 | 0.13 | 0.01 | 0.2 |
| | | | 988–1202 | 0.9–5.0 | <0.01–0.15 | <0.01–0.02 | <0.01–0.07 | 0.01–0.24 | | <0.1–0.5 |
| | 1975 | 8 | 946 | 3.1 | 0.14 | 0.01 | 0.05 | 0.20 | 0.02 | 0.3 |
| | | | 696–1154 | 0.7–7.1 | 0.03–0.46 | <0.01–0.03 | <0.01–0.15 | 0.08–0.59 | <0.01–0.06 | 0.1–0.7 |
| *Esocidae* | | | | | | | | | | |
| Northern pike | 1971 | 5 | 2044 | 1.2 | 0.23 | 0.03 | 0.14 | 0.40 | <0.01 | 0.3 |
| | | | 1474–2752 | 0.8–1.8 | 0.08–0.48 | 0.01–0.07 | 0.02–0.41 | 0.11–0.96 | | 0.1–0.6 |
| *Salmonidae* | | | | | | | | | | |
| Bloater | 1971 | 4(19)[3] | 149 | 9.7 | 0.68 | 0.07 | 0.41 | 1.16 | 0.02 | 0.6 |
| | | | 145–175 | 9.4–10.0 | 0.56–0.75 | 0.06–0.08 | 0.34–0.45 | 0.96–1.36 | 0.01–0.06 | 0.5–0.7 |
| | 1975 | 10 | 169 | 10.2 | 0.52 | 0.07 | 0.47 | 1.06 | 0.04 | 1.0 |
| | | | 112–268 | 3.1–18.7 | 0.07–1.76 | 0.02–0.16 | 0.12–1.39 | 0.22–3.23 | 0.01–0.09 | 0.3–3.7 |
| Lake trout | 1968 | 18 | 2016 | 8.0 | 1.44 | 0.24 | 1.04 | 2.72 | 0.08 | 0.7 |
| | | | 455–5506 | 1.3–14.7 | 0.16–7.11 | 0.01–1.32 | 0.02–5.68 | 0.27–14.1 | 0.01–0.26 | <0.1–2.0 |
| | 1969 | 20 | 734 | 6.4 | 0.43 | 0.12 | 0.43 | 0.98 | 0.03 | 0.3 |
| | | | 409–1700 | 1.7–14.4 | 0.20–0.75 | 0.04–0.20 | 0.19–0.77 | 0.43–1.69 | <0.01–0.05 | 0.1–0.6 |
| | 1971 | 5 | 1901 | 17.4 | 0.98 | 0.09 | 0.65 | 1.72 | 0.03 | 1.8 |
| | | | 1572–2728 | 15.7–22.1 | 0.59–1.25 | 0.06–0.11 | 0.38–0.82 | 1.03–2.18 | 0.02–0.05 | 1.1–2.3 |
| | 1975 | 10 | 1121 | 20.7 | 0.11 | 0.01 | 0.05 | 0.17 | 0.04 | 0.4 |
| | | | 555–1432 | 14.7–29.4 | 0.09–0.16 | <0.01–0.03 | 0.02–0.09 | 0.10–0.24 | 0.03–0.05 | 0.3–0.6 |
| Lake whitefish | 1971 | 5 | 959 | 12.0 | 0.35 | 0.04 | 0.35 | 0.74 | 0.04 | 0.8 |
| | | | 895–1060 | 8.5–14.2 | 0.29–0.45 | 0.03–0.05 | 0.30–0.43 | 0.63–0.93 | 0.03–0.05 | <0.1–1.0 |
| | 1975 | 10 | 1135 | 10.8 | 0.16 | 0.02 | 0.06 | 0.24 | 0.07 | 0.3 |
| | | | 766–1400 | 6.2–12.2 | 0.09–0.29 | 0.01–0.03 | <0.01–0.16 | 0.12–0.48 | 0.04–0.11 | 0.1–0.7 |

[1] In 1975 traces (0.004 ppm) of *cis*- and *trans*-chlordane were detected in some bloater, white sucker, lake trout, and lake whitefish.
[2] <0.01 ppm represents a trace of contaminant above the level of detection (0.001 ppm) but below 0.010 ppm.
[3] Composite of 19 fish.

off Grass Cap Point in 1971 had residues of 2.2 ppm and 2.3 ppm PCBs and two bloaters caught commercially in 1975 had residues of 2.1 ppm and 3.7 ppm. Mean residues for lake trout in 1971 and bloaters in 1975 were 1.8 ppm and 1.0 ppm, respectively.

TABLE 2. *Ratios of organochlorine contaminants in four species of fish caught in Lake Superior, Lake Huron, and Georgian Bay, 1968–76*

| Species | Year | DDE+TDE / ΣDDT | ΣDDT / PCBs | ΣDDT / Dieldrin | PCBs / Dieldrin |
|---|---|---|---|---|---|
| *Lake Superior* | | | | | |
| Bloater | 1971 | 0.65 | 2.0 | 50 | 30 |
| | 1975 | 0.56 | 1.1 | 30 | 25 |
| White sucker | 1971 | 0.69 | 0.5 | 21 | 20 |
| | 1975 | 0.75 | 0.8 | 10 | 15 |
| Lake trout | 1968 | 0.62 | 3.9 | 91 | 9 |
| | 1969 | 0.56 | 3.3 | 33 | 10 |
| | 1971 | 0.62 | 0.9 | 50 | 60 |
| | 1975 | 0.70 | 0.4 | 5 | 10 |
| Lake whitefish | 1971 | 0.53 | 0.9 | 19 | 20 |
| | 1975 | 0.75 | 0.8 | 3 | 4 |
| *Lake Huron (Main Lake)* | | | | | |
| Bloater | 1969 | 0.74 | 3.5 | 69 | 20 |
| | 1970 | 0.52 | 1.8 | 29 | 16 |
| | 1971 | 0.64 | 2.1 | 94 | 44 |
| Cisco | 1969 | 0.66 | 6.1 | 61 | 10 |
| | 1976 | 0.95 | 1.0 | 6 | 7 |
| Coho salmon | 1968 | 0.54 | 0.5 | 26 | 50 |
| | 1969 | 0.68 | 2.5 | 51 | 20 |
| | 1970 | 0.60 | 1.6 | 25 | 15 |
| | 1971 | 0.61 | 1.2 | 19 | 17 |
| | 1975 | 0.91 | 0.4 | 7 | 16 |
| Lake whitefish | 1969 | 0.36 | 3.6 | 9 | 2 |
| | 1972 | 0.60 | 1.4 | 9 | 7 |
| | 1973 | 0.60 | 1.2 | 8 | 7 |
| | 1976 | 0.80 | 0.6 | 2 | 3 |
| *Georgian Bay* | | | | | |
| Bloater | 1971 | 0.66 | 1.0 | 24 | 24 |
| | 1975 | 0.61 | 0.7 | 5 | 7 |
| Cisco | 1969 | 0.38 | 3.2 | 159 | 50 |
| | 1976 | 0.62 | 0.7 | 8 | 12 |

Mean PCB residues declined in lake trout and lake whitefish between 1971 and 1975 but increased in bloaters over the same period. Comparison of lake trout by weight class revealed no significant decline in PCB residues (Table 3). The ΣDDT/PCB ratio in all species declined, suggesting the disappearance of ΣDDT. The PCB/dieldrin ratio indicates that dieldrin is more persistent in fish tissues than are PCBs.

*Other organochlorines*—Trace quantities (<0.01 ppm) of *cis*- and *trans*-chlordane were detected in some bloaters, white sucker, lake trout, and lake whitefish caught in 1975, but no oxychlordane, endrin, or heptachlor epoxide was detected in fish caught in 1968–75.

### LAKE HURON

*ΣDDT*—Three fish species caught in Lake Huron and Georgian Bay contained mean residues that exceeded 5 ppm. These included walleye (5.05 ppm) caught in southern Lake Huron in 1970, lake trout (7.60 ppm) caught in Georgian Bay in 1969, and bloaters (5.18 ppm) caught in 1971 in Georgian Bay (Table 4). Individual fish of five species contained ΣDDT residues in excess of 5 ppm including: bloaters (1970 and 1971), coho salmon (1970), and walleye (1970), caught in the southern half of Lake Huron; and bloaters (1971), rainbow trout (1968), lake trout (1969), and walleye (1969 and 1970) caught in Georgian Bay (Table 4, Figure 1).

ΣDDT residues declined noticeably between 1968–71 and 1975–76 in six species including alewife (*Alosa pseudoharengus*), smallmouth bass (*Micropterus dolomieui*), cisco (*Coregonus artedii*), coho salmon, rainbow

TABLE 3. *Comparison of organochlorine residues in two weight classes of splake, lake trout, and lake whitefish caught in Lake Huron and Lake Superior, 1969–76*

| Species and Location | Year | 0.5–1.0 kg Class | | | | | | 1.0–1.5 kg Class | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | No. of Fish | Weight, g | Fat, % | ΣDDT, ppm | Dieldrin, ppm | PCBs, ppm | No. of Fish | Weight, g | Fat, % | ΣDDT, ppm | Dieldrin, ppm | PCBs, ppm |
| *Splake* | | | | | | | | | | | | | |
| Lake Huron | 1969 | 3 | 821 | 6.8 | 1.61 | 0.06 | 0.2 | 5 | 1351 | 6.9 | 0.86 | 0.03 | 0.3 |
| | 1970 | 3 | 784 | 13.2 | 1.16 | 0.06 | 1.6 | 8 | 1220 | 17.6 | 1.35 | 0.07 | 1.5 |
| | 1972 | 3 | 787 | 10.8 | 0.87 | 0.05 | 0.7 | | | | | | |
| | 1973 | 10 | 690 | 6.6 | 0.77 | 0.03 | 0.6 | 4 | 1108 | 12.2 | 0.75 | 0.06 | 0.9 |
| | 1974 | 1 | 526 | 3.3 | 0.11 | <0.01 | 0.1 | 4 | 1271 | 4.4 | 0.15 | 0.02 | 0.3 |
| Georgian Bay | 1975 | 6 | 747 | 11.9 | 0.78 | 0.14 | 1.4 | 6 | 1185 | 14.1 | 0.87 | 0.16 | 1.9 |
| *Whitefish* | | | | | | | | | | | | | |
| Lake Superior | 1971 | 3 | 910 | 12.5 | 0.71 | 0.04 | 0.8 | 2 | 1032 | 11.3 | 0.78 | 0.04 | 0.8 |
| | 1975 | 1 | 766 | 8.6 | 0.28 | 0.04 | 0.2 | 9 | 1176 | 11.0 | 0.22 | 0.07 | 0.3 |
| Lake Huron | 1969 | 22 | 730 | 5.4 | 0.40 | 0.05 | 0.1 | 1 | 1180 | 3.7 | 0.25 | 0.03 | <0.1 |
| | 1972 | 12 | 813 | 8.2 | 0.55 | 0.07 | 0.3 | 7 | 1142 | 12.3 | 0.87 | 0.09 | 0.6 |
| | 1973 | | | | | | | 7 | 1172 | 17.1 | 0.64 | 0.08 | 0.4 |
| | 1976 | 2 | 850 | 3.7 | 0.08 | 0.03 | 0.1 | 10 | 1237 | 6.3 | 0.12 | 0.07 | 0.2 |
| North Channel | 1969 | 6 | 936 | 3.2 | 0.14 | 0.01 | <0.1 | 8 | 1187 | 6.1 | 0.89 | 0.10 | 0.1 |
| | 1970 | 1 | 980 | 8.6 | 0.80 | 0.05 | 0.4 | 2 | 1285 | 10.6 | 0.71 | 0.07 | 0.4 |
| Georgian Bay | 1969 | 4 | 939 | 4.5 | 0.44 | 0.01 | 0.1 | 6 | 1131 | 3.7 | 0.54 | 0.01 | 0.2 |
| *Lake Trout* | | | | | | | | | | | | | |
| Lake Superior | 1968 | 8 | 698 | 4.8 | 0.818 | 0.046 | 0.21 | 4 | 1566 | 10.6 | 4.94 | 0.128 | 1.19 |
| | 1969 | 10 | 619 | 3.8 | 0.731 | 0.024 | 0.25 | 10 | 1308 | 8.8 | 1.25 | 0.040 | 0.34 |
| | 1970 | | | | | | | 4 | 1694 | 17.9 | 1.75 | 0.033 | 1.88 |
| | 1975 | 3 | 768 | 18.6 | 0.192 | 0.037 | 0.33 | 7 | 1272 | 21.6 | 0.17 | 0.037 | 0.49 |

smelt *(Osmerus mordax)*, and walleye from the main waters of Lake Huron, and bloaters from Georgian Bay. ΣDDT mean residues were erratic or unchanged in cisco, splake *(Salvelinus fontinalis* and *S. namaycush)*, and walleye caught in Georgian Bay and in splake and lake whitefish caught in the main lake.

To determine whether ΣDDT residues in splake and lake whitefish had declined, similar weight classes were compared (Table 3). ΣDDT levels in splake with an average weight of 1250 g declined between 1971 and 1974 from 1.35 ppm to 0.15 ppm. A similar decline in ΣDDT residues in lake whitefish was noted between 1972 and 1976. Cisco, coho salmon, and lake whitefish all showed a marked increase in the DDE+TDE/ΣDDT ratio during the present study (Table 2), suggesting a lower intake of the parent compound and/or degradation to metabolites; this decline was not evident in bloaters.

*Dieldrin*—Mean residues for all species investigated did not exceed the 0.3 ppm tolerance level set by FDA. However, individual fish of three species exceeded the level. One of 20 lake whitefish caught in the North Channel in 1969 contained 0.58 ppm dieldrin; one of 10 bloaters caught in Lake Huron in 1970 had a residue of 0.44 ppm dieldrin; five of 10 bloaters caught in Georgian Bay in 1975 contained dieldrin levels of 0.34–0.50 ppm; 10 of 20 bloaters caught in the North Channel in 1975 contained residues of 0.3–0.6 ppm dieldrin; and two large splake caught in Lake Huron contained residues of 0.43 ppm and 0.53 ppm dieldrin. The 10 bloaters caught in the North Channel during 1975, which had residues above the tolerance level, weighed an average of 333 g and contained an average of 0.40 ppm dieldrin. The remaining 10 bloaters, which averaged 236 g, contained a mean residue of 0.19 ppm dieldrin. In this instance, and in the case of the splake, higher dieldrin residues were associated with larger fish, but this relationship was not apparent in the 10 bloaters caught in Georgian Bay in 1975 (Table 4).

Dieldrin levels increased in alewife, bloaters, cisco, yellow perch *(Perca flavescens)*, coho salmon, and splake during 1968–71 and 1975–76; levels in other species showed little change. Assessment of dieldrin levels on the basis of similar weight classes of lake whitefish and splake indicate that residues declined in lake whitefish and increased in splake (Table 3). A marked decline was noted in the ΣDDT/dieldrin ratio in four species: in cisco, for example, the ratio declined from 61 to 6 between 1969 and 1976. The PCB/dieldrin ratio also declined in the same four species suggesting declining PCB residues and static or increasing dieldrin residues (Table 2).

*PCBs*—Three fish species contained mean PCB residues which exceeded the 2 ppm tolerance level set by Health and Welfare Canada. Bloaters from the main lake (1970 and 1971), from Georgian Bay (1971 and 1975), and from the North Channel (1975) contained mean residues of 2.2–5.2 ppm. Individual bloaters had residues as high as 5.0 ppm and 6.4 ppm (Table 4). Cisco netted in Georgian Bay during 1975 contained a mean PCB residue of 2.2 ppm and a high level of 4.6 ppm in individual fish. Two large splake taken from the main waters of Lake Huron in 1975 contained levels of 5.5 ppm and 6.4 ppm PCBs.

TABLE 4. *Organochlorine residues in 14 fish species caught in the North Channel, Georgian Bay, and Canadian waters of Lake Huron, 1968–76*

| Species | Year | Location | No. of Analyses[1] | Mean and Range Weight, g | Fat, % | Mean Content and Range of Contaminants in Fish Puree, ppm[2] DDE | TDE | DDT | Σ DDT | Dieldrin | PCBs |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Catostomidae* | | | | | | | | | | | |
| White sucker | 1972 | Huron | 5 | 723 | 2.5 | 0.08 | 0.01 | 0.02 | 0.11 | <0.01 | 0.1 |
| | | | | 550–909 | 1.8–3.3 | 0.05–0.13 | <0.01–0.03 | <0.01–0.06 | 0.06–0.22 | | <0.1–0.2 |
| | 1973 | Georgian Bay | 4 | 131 | 0.7 | <0.01 | <0.01 | <0.01 | 0.01 | <0.01 | 0.1 |
| | | | | 66–212 | 0.2–1.0 | <0.01–0.02 | | | <0.01–0.03 | | <0.1–0.2 |
| | 1976 | Huron | 10 | 977 | 0.6 | 0.06 | <0.01 | 0.02 | 0.09 | <0.01 | 0.1 |
| | | | | 738–1837 | 0.1–1.1 | <0.01–0.20 | | <0.01–0.14 | <0.01–0.37 | | <0.1–0.2 |
| *Centrachidae* | | | | | | | | | | | |
| Smallmouth bass | 1968 | Huron | 3 | 499 | 3.1 | 0.68 | 0.76 | 0.53 | 1.97 | <0.01 | 0.9 |
| | | | | 429–630 | 2.0–4.9 | 0.12–1.69 | 0.15–2.02 | 0.12–1.23 | 0.30–4.94 | | 0.2–2.0 |
| | 1972 | Huron | 5 | 353 | 3.7 | 0.12 | 0.01 | 0.03 | 0.16 | 0.01 | 0.4 |
| | | | | 298–437 | 2.6–4.5 | 0.11–0.13 | | 0.02–0.04 | 0.15–0.18 | <0.01–0.03 | 0.3–0.5 |
| | 1972 | Georgian Bay | 6 | 281 | 2.8 | 0.05 | 0.01 | <0.01 | 0.07 | <0.01 | 0.01 |
| | | | | 270–300 | 1.6–4.0 | 0.04–0.07 | 0.01–0.02 | | 0.06–0.10 | | 0.1–0.1 |
| | 1975 | Georgian Bay | 9 | 364 | 3.2 | 0.17 | 0.01 | 0.03 | 0.21 | 0.03 | 0.6 |
| | | | | 275–562 | 1.7–4.5 | 0.09–0.28 | <0.01–0.04 | <0.01–0.08 | 0.12–0.36 | <0.01–0.09 | 0.4–0.9 |
| *Clupeidae* | | | | | | | | | | | |
| Alewife | 1970 | Huron | 8(21) | 33 | 7.5 | 0.76 | 0.23 | 0.64 | 1.63 | 0.08 | 1.1 |
| | | | | 26–40 | 1.5–13.2 | 0.16–1.40 | 0.04–0.52 | 0.22–1.48 | 0.27–3.40 | 0.01–0.22 | 0.5–2.0 |
| | 1976 | Huron | 5(23) | 23 | 10.7 | 0.44 | 0.10 | 0.26 | 0.80 | 0.14 | 0.3 |
| | | | | 3–49 | 5.8–16.9 | 0.04–1.08 | 0.01–0.12 | 0.01–0.54 | 0.06–1.74 | <0.01–0.25 | 0.1–0.6 |
| *Osmeridae* | | | | | | | | | | | |
| Rainbow smelt | 1970 | Huron | 8(21) | 22 | 6.5 | 0.36 | 0.12 | 0.32 | 0.80 | 0.04 | 0.7 |
| | | | | 12–67 | 4.0–8.4 | 0.06–0.97 | 0.01–0.25 | 0.02–0.80 | 0.11–1.86 | <0.01–0.15 | 0.2–1.0 |
| | 1970 | N. Channel | 5(24) | 26 | 3.6 | 0.12 | 0.04 | 0.15 | 0.31 | 0.02 | 0.1 |
| | | | | 18–44 | 2.8–4.4 | 0.05–0.20 | 0.03–0.05 | 0.08–0.20 | 0.15–0.45 | <0.01–0.03 | |
| | 1976 | Huron | 7(32) | 14 | 2.7 | 0.11 | 0.02 | 0.02 | 0.15 | 0.01 | 0.01 |
| | | | | 7–30 | 1.2–3.9 | 0.05–0.19 | 0.01–0.02 | <0.01–0.03 | 0.08–0.23 | <0.01–0.02 | <0.1–0.2 |
| *Percidae* | | | | | | | | | | | |
| Yellow perch | 1968 | Huron | 5 | 335 | 0.8 | 0.20 | 0.12 | 0.20 | 0.52 | <0.01 | 0.2 |
| | | | | 118–426 | 0.5–1.0 | 0.06–0.61 | 0.02–0.47 | 0.08–0.51 | 0.16–1.59 | | <0.1–0.5 |
| | 1969 | N. Channel | 20 | 201 | 1.4 | 0.03 | 0.01 | 0.03 | 0.07 | <0.01 | <0.1 |
| | | | | 167–341 | 0.5–2.4 | <0.01–0.08 | <0.01–0.03 | <0.01–0.05 | <0.01–0.18 | | |
| | 1972 | Huron | 5 | 67 | 4.4 | 0.07 | 0.01 | 0.03 | 0.11 | 0.01 | 0.1 |
| | | | | 64–74 | 3.8–5.3 | 0.06–0.08 | 0.01 | 0.02–0.03 | 0.09–0.12 | <0.01–0.02 | |
| | 1975 | N. Channel | 10 | 175 | 6.1 | 0.36 | 0.03 | 0.09 | 0.48 | 0.05 | 0.9 |
| | | | | 150–197 | 3.5–8.6 | 0.13–0.57 | <0.01–0.05 | <0.01–0.17 | 0.13–0.72 | 0.02–0.09 | 0.4–1.4 |
| | 1976 | Huron | 17 | 236 | 2.5 | 0.21 | 0.03 | 0.08 | 0.32 | 0.02 | 0.2 |
| | | | | 66–481 | 0.7–5.4 | 0.06–0.68 | 0.01–0.08 | 0.01–0.55 | 0.07–1.31 | <0.01–0.05 | <0.1–0.4 |
| Walleye | 1968 | Huron | 3 | 409 | 0.8 | 0.12 | 0.04 | 0.13 | 0.29 | <0.01 | 0.1 |
| | | | | 390–426 | 0.6–0.9 | 0.06–0.22 | 0.02–0.07 | 0.08–0.21 | 0.16–0.50 | | <0.1–0.1 |
| | 1969 | Georgian Bay | 15 | 2073 | 2.6 | 1.05 | 0.24 | 1.08 | 2.37 | 0.02 | 1.5 |
| | | | | 792–4190 | 0.6–6.0 | 0.23–3.53 | 0.06–0.81 | 0.23–4.03 | 0.54–8.36 | <0.01–0.07 | 0.5–2.1 |
| | 1970 | Huron | 2 | 2083 | 10.1 | 2.37 | 0.64 | 2.04 | 5.05 | 0.08 | 1.3 |
| | | | | 1910–2255 | 9.7–10.4 | 1.80–2.91 | 0.43–0.84 | 1.65–2.47 | 3.88–6.22 | 0.06–0.08 | 0.7–1.9 |
| | 1970 | Georgian Bay | 21 | 3236 | 4.7 | 0.94 | 0.23 | 0.98 | 2.15 | 0.04 | 1.4 |
| | | | | 1721–4760 | 1.2–10.6 | 0.23–3.70 | 0.04–0.85 | 0.18–3.88 | 0.45–8.33 | <0.01–0.16 | 0.5–2.3 |
| | 1970 | N. Channel | 3 | 605 | 2.1 | 0.19 | 0.04 | 0.16 | 0.39 | <0.01 | 0.1 |
| | | | | 526–715 | 1.3–3.5 | 0.16–0.23 | 0.04–0.05 | 0.13–0.21 | 0.34–0.49 | | <0.1–0.1 |
| | 1971 | Georgian Bay | 10 | 2859 | 5.8 | 1.74 | 0.21 | 1.11 | 3.06 | 0.03 | 1.8 |
| | | | | 1132–4756 | 2.9–11.6 | 0.08–4.08 | 0.04–0.37 | 0.04–2.32 | 0.16–6.93 | <0.01–0.07 | 0.1–3.9 |
| | 1975 | Huron | 10 | 2539 | 4.7 | 0.38 | 0.05 | 0.27 | 0.70 | 0.03 | 0.5 |
| | | | | 722–5218 | 1.5–13.3 | 0.16–1.01 | <0.01–0.15 | 0.03–1.01 | 0.27–2.17 | 0.01–0.13 | 0.3–2.5 |
| *Salmonidae* | | | | | | | | | | | |
| Bloater | 1969 | Huron | 15 | 97 | 3.0 | 0.39 | 0.12 | 0.18 | 0.69 | 0.01 | 0.2 |
| | | | | 55–143 | 1.4–7.7 | 0.06–1.54 | 0.02–0.50 | 0.04–0.66 | 0.20–2.71 | <0.01–0.02 | <0.1–0.7 |
| | 1970 | Huron | 10 | 260 | 16.0 | 1.95 | 0.49 | 2.24 | 4.68 | 0.16 | 2.6 |
| | | | | 148–307 | 8.1–26.7 | 1.00–3.69 | 0.20–1.03 | 1.01–5.17 | 2.48–9.88 | 0.04–0.44 | 1.5–5.0 |
| | 1971 | Huron | 6 | 71 | 15.0 | 2.73 | 0.29 | 1.69 | 4.71 | 0.05 | 2.2 |
| | | | | 61–101 | 7.2–21.1 | 2.02–4.34 | 0.05–0.78 | 1.14–2.40 | 3.44–7.52 | 0.03–0.07 | 1.1–3.2 |
| | 1971 | Georgian Bay | 4(12) | 259 | 20.1 | 2.90 | 0.53 | 1.75 | 5.18 | 0.22 | 5.2 |
| | | | | 140–433 | 18.0–23.0 | 2.34–3.83 | 0.29–0.75 | 1.63–1.85 | 4.26–6.43 | 0.18–0.28 | 4.3–6.4 |
| | 1975 | Georgian Bay | 10 | 219 | 16.3 | 0.71 | 0.16 | 0.56 | 1.43 | 0.30 | 2.2 |
| | | | | 179–250 | 8.1–20.1 | 0.33–1.15 | 0.01–0.30 | 0.15–1.11 | 0.49–2.56 | 0.10–0.50 | 0.8–4.4 |
| | 1975 | N. Channel | 20 | 285 | 22.9 | 1.16 | 0.17 | 0.54 | 1.87 | 0.29 | 2.6 |
| | | | | 134–560 | 15.5–29.8 | 0.56–2.34 | <0.01–0.41 | 0.01–1.48 | 0.74–4.18 | <0.01–0.60 | 0.6–5.2 |
| Cisco | 1969 | Huron | 2 | 180 | 5.4 | 0.35 | 0.05 | 0.21 | 0.61 | 0.01 | 0.1 |
| | | | | 100–260 | 2.0–8.8 | 0.18–0.52 | 0.02–0.07 | 0.07–0.35 | 0.27–0.94 | <0.01–0.02 | <0.1–0.2 |
| | 1969 | Georgian Bay | 10 | 820 | 7.2 | 0.41 | 0.19 | 0.99 | 1.59 | 0.01 | 0.5 |
| | | | | 337–937 | 4.8–9.4 | 0.22–1.01 | 0.08–0.40 | 0.54–2.58 | 0.83–3.99 | <0.01–0.02 | 0.2–1.1 |
| | 1975 | Georgian Bay | 6 | 543 | 18.0 | 0.78 | 0.15 | 0.58 | 1.51 | 0.19 | 2.2 |
| | | | | 352–710 | 11.3–24.7 | 0.47–1.14 | 0.09–0.29 | 0.26–1.22 | 0.83–2.65 | 0.12–0.30 | 1.3–4.6 |
| | 1976 | Huron | 9(11) | 138 | 5.0 | 0.14 | 0.05 | 0.01 | 0.20 | 0.03 | 0.2 |
| | | | | 47–242 | 3.0–7.5 | 0.11–0.19 | 0.03–0.09 | <0.01–0.02 | 0.14–0.29 | 0.01–0.08 | 0.1–0.4 |

(*continued next page*)

TABLE 4. (cont.d.) *Organochlorine residues in 14 fish species caught in the North Channel, Georgian Bay, and Canadian waters of Lake Huron, 1968–76*

| Species | Year | Location | No. of Analyses[1] | Mean and Range Weight, g | Mean and Range Fat, % | Mean Content and Range of Contaminants in Fish Puree, ppm[2] DDE | TDE | DDT | ΣDDT | Dieldrin | PCBs |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Coho salmon | 1968 | Huron | 8 | 81 | 3.9 | 0.11 | 0.03 | 0.12 | 0.26 | <0.01 | 0.5 |
| | | | | 39–163 | 1.2–5.4 | 0.04–0.42 | 0.01–0.12 | 0.04–0.43 | 0.09–0.97 | 0.01–0.03 | 0.2–1.0 |
| | 1969 | Huron | 5 | 1885 | 5.8 | 0.88 | 0.16 | 0.48 | 1.52 | 0.03 | 0.6 |
| | | | | 1138–3335 | 5.1–6.5 | 0.31–2.01 | 0.13–0.21 | 0.35–0.62 | 0.87–2.84 | 0.01–0.05 | 0.3–1.2 |
| | 1970 | Huron | 41 | 1031 | 4.9 | 0.48 | 0.11 | 0.39 | 0.98 | 0.04 | 0.6 |
| | | | | 754–1595 | 0.8–11.1 | 0.9–5.2 | 0.03–0.66 | 0.08–1.89 | 0.22–7.75 | 0.01–0.24 | 0.1–7.0 |
| | 1971 | Huron | 10 | 936 | 8.0 | 0.50 | 0.20 | 0.45 | 1.15 | 0.06 | 1.0 |
| | | | | 475–1395 | 4.9–13.0 | 0.23–1.15 | 0.07–0.62 | 0.16–0.80 | 0.48–2.09 | 0.02–0.13 | 0.2–2.1 |
| | 1975 | Huron | 11 | 2284 | 5.8 | 0.43 | 0.05 | 0.05 | 0.53 | 0.08 | 1.3 |
| | | | | 280–4356 | 3.9–8.4 | 0.04–0.94 | <0.01–0.14 | <0.01–0.19 | 0.05–1.22 | 0.01–0.16 | 0.1–3.3 |
| Kokanee salmon | 1968 | Huron | 2 | 95 | 3.5 | 0.44 | 0.12 | 0.59 | 1.15 | 0.04 | 0.3 |
| | | | | 94–96 | 2.8–4.2 | 0.08–0.80 | 0.02–0.22 | 0.10–1.08 | 0.20–2.00 | <0.01–0.07 | 0.1–0.4 |
| | 1969 | Huron | 11 | 98 | 3.3 | 0.10 | 0.03 | 0.10 | 0.23 | 0.01 | <0.1 |
| | | | | 58–375 | 1.4–5.3 | 0.02–0.80 | <0.01–0.06 | 0.03–0.18 | 0.06–0.57 | <0.01–0.03 | |
| | 1970 | Huron | 15 | 512 | 4.1 | 0.38 | 0.12 | 0.45 | 0.95 | 0.04 | 0.6 |
| | | | | 204–1098 | 0.9–7.8 | 0.17–0.67 | 0.05–0.24 | 0.16–1.03 | 0.78–1.76 | <0.01–0.12 | 0.2–1.0 |
| Splake | 1969 | Huron | 20 | 1113 | 6.3 | 0.43 | 0.14 | 0.46 | 1.03 | 0.04 | 0.2 |
| | | | | 25–2354 | 1.8–10.1 | 0.03–0.85 | 0.02–0.33 | 0.03–0.85 | 0.08–2.11 | <0.01–0.09 | <0.1–0.5 |
| | 1970 | Huron | 23 | 810 | 10.2 | 0.37 | 0.13 | 0.50 | 1.00 | 0.04 | 1.0 |
| | | | | 208–1420 | 3.2–15.7 | 0.12–0.82 | 0.04–0.20 | 0.01–1.03 | 0.19–1.81 | <0.01–0.12 | 0.1–1.5 |
| | 1972 | Huron | 5 | 544 | 8.5 | 0.30 | 0.04 | 0.28 | 0.62 | 0.03 | 0.5 |
| | | | | 138–877 | 5.1–11.7 | 0.14–0.44 | 0.01–0.04 | 0.08–0.56 | 0.23–1.10 | 0.01–0.05 | 0.2–0.9 |
| | 1973 | Huron | 26 | 556 | 8.8 | 0.38 | 0.03 | 0.06 | 0.47 | 0.03 | 0.4 |
| | | | | 96–450 | 3.6–16.1 | 0.03–1.20 | <0.01–0.13 | <0.01–0.16 | 0.04–1.31 | <0.01–0.10 | <0.1–1.5 |
| | 1974 | Huron | 7 | 1238 | 4.1 | 0.11 | 0.01 | 0.03 | 0.15 | 0.02 | 0.2 |
| | | | | 526–1540 | 2.7–5.9 | 0.06–0.19 | <0.01–0.02 | <0.01–0.05 | 0.08–0.25 | <0.01–0.04 | <0.1–0.7 |
| | 1975 | Huron | 2 | 2127 | 17.2 | 1.80 | 0.42 | 0.46 | 2.68 | 0.48 | 6.0 |
| | | | | 1997–2256 | 13.6–20.8 | 1.58–2.02 | 0.40–0.44 | 0.37–0.55 | 2.39–2.97 | 0.43–0.53 | 5.5–6.4 |
| | 1975 | Georgian Bay | 17 | 1048 | 13.3 | 0.52 | 0.08 | 0.18 | 0.78 | 0.15 | 1.6 |
| | | | | 458–1798 | 8.5–17.4 | 0.18–0.88 | 0.03–0.11 | 0.10–0.37 | 0.28–1.12 | 0.08–0.18 | 0.6–2.3 |
| Rainbow trout | 1968 | Georgian Bay | 12 | 857 | 5.5 | 0.74 | 0.17 | 0.84 | 1.75 | 0.04 | 0.3 |
| | | | | 284–1850 | 3.2–7.8 | 0.12–6.17 | 0.02–1.27 | 0.13–5.70 | 0.27–13.1 | <0.01–0.19 | <0.1–1.5 |
| Lake trout | 1969 | Georgian Bay | 4 | 6328 | 13.4 | 4.04 | 0.50 | 3.06 | 7.60 | 0.07 | 0.7 |
| | | | | 4200–8740 | 12.9–13.8 | 3.14–5.51 | 0.45–0.63 | 2.66–3.71 | 6.28–9.85 | 0.06–0.09 | 0.4–0.9 |
| Lake whitefish | 1969 | N. Channel | 20 | 1430 | 4.8 | 0.13 | 0.07 | 0.36 | 0.56 | 0.06 | 0.1 |
| | | | | 854–2785 | 0.8–8.9 | 0.03–1.58 | 0.01–0.31 | 0.66–2.66 | 0.10–4.75 | <0.01–0.58 | <0.1–0.7 |
| | 1969 | Huron | 26 | 711 | 5.0 | 0.13 | 0.05 | 0.18 | 0.36 | 0.04 | 0.1 |
| | | | | 386–1080 | 2.9–9.9 | 0.07–0.24 | 0.02–0.10 | 0.04–0.36 | 0.16–0.73 | <0.01–0.08 | <0.1–0.3 |
| | 1969 | Georgian Bay | 10 | 1054 | 4.0 | 0.20 | 0.09 | 0.22 | 0.51 | 0.01 | 0.2 |
| | | | | 881–1241 | 3.2–6.4 | 0.10–0.31 | 0.03–0.13 | 0.09–0.33 | 0.22–0.78 | <0.01–0.02 | <0.1–0.3 |
| | 1970 | N. Channel | 3 | 1183 | 9.9 | 0.27 | 0.07 | 0.40 | 0.74 | 0.06 | 0.4 |
| | | | | 980–1361 | 8.6–11.7 | 0.23–0.29 | 0.07 | 0.33–0.45 | 0.63–0.80 | 0.05–0.09 | 0.2–0.5 |
| | 1972 | Huron | 25 | 761 | 8.2 | 0.28 | 0.65 | 0.22 | 0.55 | 0.06 | 0.04 |
| | | | | 80–1393 | 1.8–21.9 | 0.07–1.02 | 0.01–0.16 | 0.03–0.42 | 0.11–1.47 | 0.01–0.11 | 0.1–0.8 |
| | 1973 | Huron | 19 | 804 | 14.2 | 0.23 | 0.05 | 0.19 | 0.47 | 0.06 | 0.04 |
| | | | | 108–1747 | 6.9–26.5 | 0.03–1.48 | 0.01–0.21 | 0.02–0.92 | 0.07–2.61 | <0.01–0.25 | <0.1–0.6 |
| | 1976 | Huron | 15 | 1323 | 5.8 | 0.08 | 0.02 | 0.03 | 0.13 | 0.06 | 0.2 |
| | | | | 802–2495 | 2.5–11.6 | 0.04–0.15 | 0.01–0.03 | 0.02–0.05 | 0.07–0.23 | 0.03–0.14 | 0.1–0.5 |

[1] Most analyses were performed on single fish; where composites were analyzed, the number of fish is given in parentheses. Composities were of similar weight.
[2] <0.01 ppm represents a trace of contaminant above the level of detection (0.001 ppm) but below 0.010 ppm.

Alewife, rainbow smelt, and walleye caught in the main waters of Lake Huron were the only species in which PCB levels declined between 1968–71 and 1975–76. Residues in cisco from Georgian Bay, yellow perch from the North Channel, and coho salmon and splake from the main lake increased during these periods. In the above species caught in other locations and in other species, no trend was evident; PCB levels were static. Analysis of splake and lake whitefish on the basis of similar weight classes indicates that PCB levels peaked in splake in 1970 and then declined between 1970 and 1974. PCB levels in lake whitefish declined between 1972 and 1976 (Table 3).

In general, the ΣDDT/PCB and PCB/dieldrin ratios declined between 1968–71 and 1975–76 in four species: bloaters, cisco, coho salmon, and lake whitefish; this supported the finding that ΣDDT residues were declining, dieldrin residues were increasing, and PCB residues were static or declining slowly (Table 2).

*Chlordane*—Residues of chlordane were detected in smallmouth bass and walleye caught in Georgian Bay in 1975 at mean levels of 0.01 ppm and 0.05 ppm, respectively (sum of *cis*- and *trans*-isomers). Trace levels (<0.01 ppm) were suspected in bloaters, cisco, coho salmon, and splake in 1975. Oxychlordane analysis was included in 1976. Total chlordane levels found in 1976 ranged from traces in yellow perch to 0.039 ppm in alewife; both species were caught in the open part of Lake Huron (Table 5).

TABLE 5. *Residues of chlordane and heptachlor epoxide in fish from the main waters of Lake Huron and Georgian Bay, 1975–76*

| Location and Species | No. of Fish[1] | Average Weight, g | Average Fat, % | Residue, ppm | |
|---|---|---|---|---|---|
| | | | | Chlordane[2] | Heptachlor Epoxide |
| *1975 Georgian Bay* | | | | | |
| Smallmouth bass | 9 | 364 | 3.2 | 0.01<br><0.01–0.04 | ND |
| Walleye | 10 | 2539 | 4.7 | 0.05<br><0.01–0.19 | ND |
| *1976 Lake Huron* | | | | | |
| Alewife | 23(5)[2] | 23 | 10.7 | 0.039<br>0.004–0.060 | 0.026<br>ND–0.100 |
| Cisco | 11(9) | 138 | 5.0 | 0.025<br>0.015–0.040 | 0.013<br>ND–0.044 |
| Yellow perch | 17 | 236 | 2.5 | <0.001<br>ND–0.013 | 0.002<br>ND–0.009 |
| Rainbow smelt | 32(7) | 14 | 2.7 | 0.002<br>ND–0.013 | 0.004<br>ND–0.007 |
| White sucker | 10 | 977 | 0.6 | 0.001<br>ND–0.013 | 0.002<br>ND–0.006 |
| Lake whitefish | 15 | 1323 | 5.8 | 0.047<br>0.025–0.087 | 0.026<br>0.013–0.065 |

NOTE: ND=not detected to less than 0.005 ppm.
[1]Number in brackets represents number of analysis.
[2]1975 analyses included *cis*- and *trans*-isomers; 1976 analyses included *cis*- and *trans*-chlordane and oxychlordane.

*Heptachlor epoxide*—No heptachlor epoxide was identified in fish caught prior to 1976. Mean residues in alewife caught in 1976 ranged from 0.002 ppm in yellow perch to 0.026 ppm in alewife caught in the main lake (Table 5).

*Hexachlorobenzene (HCB)*—Analyses for HCB in fish tissues were not routinely carried out during the study period. An indication of the extent of HCB in fish was obtained from samples caught in 1972 and 1973 from Lake Huron. One of five splake caught in the open lake contained 0.001 ppb HCB, and smelt caught off Black Stone Harbour in Georgian Bay contained 0.03 ppm. HCB was not detected in a limited number of smallmouth bass, yellow perch, or lake whitefish from either Georgian Bay or the main lake.

## *Discussion*

Lake Superior water analyzed by Glooschenko et al. *(3)* was free of DDT, dieldrin, and PCBs down to the detection limit. However, residues of these contaminants were found in sediment and seston. Sediment samples taken from various sites in the Canadian waters of Lake Superior had measurable amounts (0.005 ppm) of dieldrin and ΣDDT in 14 percent and 5 percent, respectively. PCB residues were present in all sediments at all sites; highest level reported was 1.3 ppm in samples collected near Marathon. Seston contained only traces of ΣDDT and dieldrin, but the mean level of PCBs was 1.3 ppm, identical to that in the sediments.

Levels of ΣDDT and dieldrin in lake trout caught in 1970 in Lake Superior correspond closely with those reported by Reinhert *(7)* in 1966–67. Residues in lake trout reported in the present study did not agree with those cited in the Upper Great Lakes Reference Group report *(11)*. However, bloaters contained similar residues in two studies.

Measurable levels of ΣDDT were reported by Glooschenko et al. in 29 percent of sediments taken from various sites in the Canadian waters of Lake Huron and in 14 percent of sediments taken from Georgian Bay *(3)*; maximum levels in both Lake Huron and Georgian Bay were 0.02 ppm. Dieldrin was present at trace levels, and PCBs ranged up to 0.02 ppm. ΣDDT and dieldrin in sediments from the North Channel were below detection levels, but traces of PCBs were found. Organochlorines were highest in seston from the open lake, ranging from 0.8 to 8.1 ppm compared to 0.7 to 6.7 ppm in Georgian Bay and a high level of 1.0 ppm in the North Channel.

Residue levels of ΣDDT and dieldrin in fish from Lake Huron and Georgian Bay reported in this paper correspond closely to the levels reported previously by Reinhert *(7)* and Reinke et al. *(9)* for alewife, bloaters, kokanee *(Oncorhynchus nerka)*, rainbow smelt, and walleye, but discrepancies are evident in yellow perch, lake whitefish, and rainbow trout. ΣDDT mean residues of 2.44 ppm are reported by Reinhert for alewife caught in 1966–67 *(7)*; the present study reveals a decline to 1.63 ppm ΣDDT mean residues in 1970 and a further decline to 0.80 ppm ΣDDT by 1976; conversely, dieldrin levels were slightly higher in 1976 (0.14 ppm) than in 1966–67 (0.05 ppm). Levels of ΣDDT in rainbow trout show little change between the 1966–67 study and those detected in 1970 in the present study, 0.75 and 0.8 ppm, respectively. However, a marked decline to a mean residue of 0.15 ppm by 1976 occurred in rainbow trout caught in Lake Huron. A mean level of 4.7 ppm ΣDDT in bloaters caught in 1970–71 in the present study is similar to levels of 3.6 ppm and 3.08 ppm reported respectively by Reinhert *(7)* in 1966 and Reinke et al. *(9)* in 1970. Mean levels of ΣDDT, dieldrin, and PCBs in bloaters in the present study closely parallel those reported by the Upper Great Lakes Reference Group *(11)* for 1975–76.

Reinke et al. found 6.02 ppm ΣDDT in walleye caught in 1970 in the main waters of Lake Huron *(9)*; this is close to the mean level of 5.05 ppm reported here. Reinke et al. reported 0.47 ppm ΣDDT in walleye caught in 1970 in Georgian Bay *(9)*, but the present study reports mean levels of 2.2 ppm and 3.1 ppm, respectively, for 1970 and 1971. This discrepancy may be partly explained by the fact that the walleye in the present study were obtained at the mouth of the Moon River, an area where high DDT residues were reported *(2, 6)*.

Residues in kokanee from Lake Huron reported here are similar to those reported by Reinke et al. *(9)* but ΣDDT

residues of 0.52 ppm in yellow perch reported in the present study are considerably lower than the mean values of 1.59 ppm in 1966–67 and 1.46 ppm in 1970 reported by Reinhert *(7)* and Reinke et al. *(9)*, respectively. Mean ΣDDT residues in lake whitefish in the present study are also markedly lower than those reported previously *(7, 9)*.

Although there are differences in the data for ΣDDT levels in coho salmon between the present study and earlier reports, there is more similarity among coho salmon from the same location. Reinke et al. reported a mean of 1.26 ppm ΣDDT and 0.08 ppm dieldrin for fish caught in northern Lake Huron *(9)*; the present study shows mean levels of 0.98 ppm ΣDDT and 0.04 ppm dieldrin for 41 coho salmon caught in the same area. ΣDDT levels in rainbow trout caught in southern Georgian Bay vary considerably from those reported previously. Reinke et al. reported a mean of 8.7 ppm ΣDDT in rainbow trout caught in 1970 *(9)*, but only 1.75 ppm ΣDDT was found in the same species caught in the same location in 1968 for the present survey. This discrepancy may be due to local differences in ΣDDT use.

Despite the number of variables which are associated with a sampling study of this kind, it is remarkable that such close agreement is found between different studies in different time frames for such large bodies of water as Lakes Superior and Huron. Other factors that cause fluctuations in contaminant concentrations in fish tissues are spawning times and changes in fat content.

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# *Residues of Organochlorine Insecticides and Polychlorinated Biphenyls in Fish from Lakes Saint Clair and Erie, Canada—1968–76*[1]

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ABSTRACT

*Eighteen species of fish from Lake Saint Clair and 19 species from Lake Erie were analyzed for organochlorine pesticides and polychlorinated biphenyls (PCBs) between 1968 and 1976. Mean residues of ΣDDT peaked at 1.19 ppm in longnose gar* (Lepisosteus osseus) *caught in Lake Saint Clair in 1970–71, but had declined in all species by 1975–76. Dieldrin levels in fish tissues increased over the same period. White bass* (Morone chrysops), *caught in 1975 in Lake Erie, had the highest mean residue of dieldrin at 0.17 ppm. PCB residues increased in some species and decreased in others. PCB residues exceeding the tolerance level of Health and Welfare Canada were found in the following: from Lake Saint Clair, smallmouth bass* (Micropterus dolomieui) *in 1975 and channel catfish* (Ictalurus punctatus) *in 1971; from Lake Erie, coho salmon* (Oncorhynchus kisutch) *in 1970, smallmouth bass, alewife* (Alosa pseudoharengus), *freshwater drum* (Aplodinotus grunniens), *and gizzard shad* (Dorosoma cepedianum) *in 1971, and white bass in 1971 and 1976.*

*Sediments in Lake Erie were five to ten times more highly contaminated with ΣDDT, dieldrin, and PCBs than were sediments from Lake Saint Clair. ΣDDT and dieldrin residues in fish tissues did not necessarily reflect this trend, but PCBs were higher in fish from Lake Erie.*

## *Introduction*

DDT, dieldrin, and PCBs have been identified in fish from Lake Erie and Lake Saint Clair. Reinert reported residues of ΣDDT in 14 species caught in 1967–68 that ranged from 0.25 ppm in spottail shiner (*Notropis hudsonius*) to 1.89 ppm in white bass (*Morone chrysops*) (*11*). Dieldrin was not detected in nine species; maximum dieldrin levels found in alewife (*Alosa pseudoharengus*) were 0.15 ppm. Reinke et al. found similar residues in six species caught in 1970 (*13*). The highest residues of ΣDDT were 0.56 ppm in alewife. Carr et al. reported on six species caught in 1970–71 (*2*). Coho salmon (*Oncorhynchus kisutch*) contained the highest mean residues of ΣDDT and dieldrin, 0.90 ppm and 0.07 ppm, respectively; channel catfish (*Ictalurus punctatus*) had the highest mean PCB residues: 4.4 ppm. Kelso and Frank found that ΣDDT and dieldrin residues varied with time of catch in three species from the eastern basin of Lake Erie (*7*). Residues were generally low; higher residue levels were associated with fish having a higher fat content.

Watersheds on the Canadian side of Lakes Erie and Saint Clair drain the most intensive agricultural belt in Ontario (Figure 1). Before restrictions on the use of aldrin, dieldrin, and heptachlor in 1969 and ΣDDT in 1970–71, this area accounted for 90 percent of organochlorine insecticides used in Ontario. Miles and Harris (*9, 10*) and Frank et al. (*3, 4*) reported that DDT and dieldrin were deposited in Lake Erie by creeks draining areas of intensive pesticide use. Frank et al. found that fish caught in the streams and creeks had residues of ΣDDT and dieldrin that were one order of magnitude higher than those caught in the adjoining waters of Lake Erie (*4*).

The present study was initiated in 1968 to determine organochlorine residues in fish before legislative restriction of the use of these materials. After use of the materials was restricted, monitoring of fish tissue was continued to determine the impact of these actions. At the same time, PCBs were identified in fish in both lakes, and monitoring for these contaminants was included to determine whether the voluntary restrictions on their use since 1971 were reflected in residue levels in fish tissue.

## *Methods and Materials*

Twenty-eight species of fish were caught by gill net or trap net between 1968 and 1976 in Lakes Saint Clair and Erie (Table 1). Most were obtained from the field

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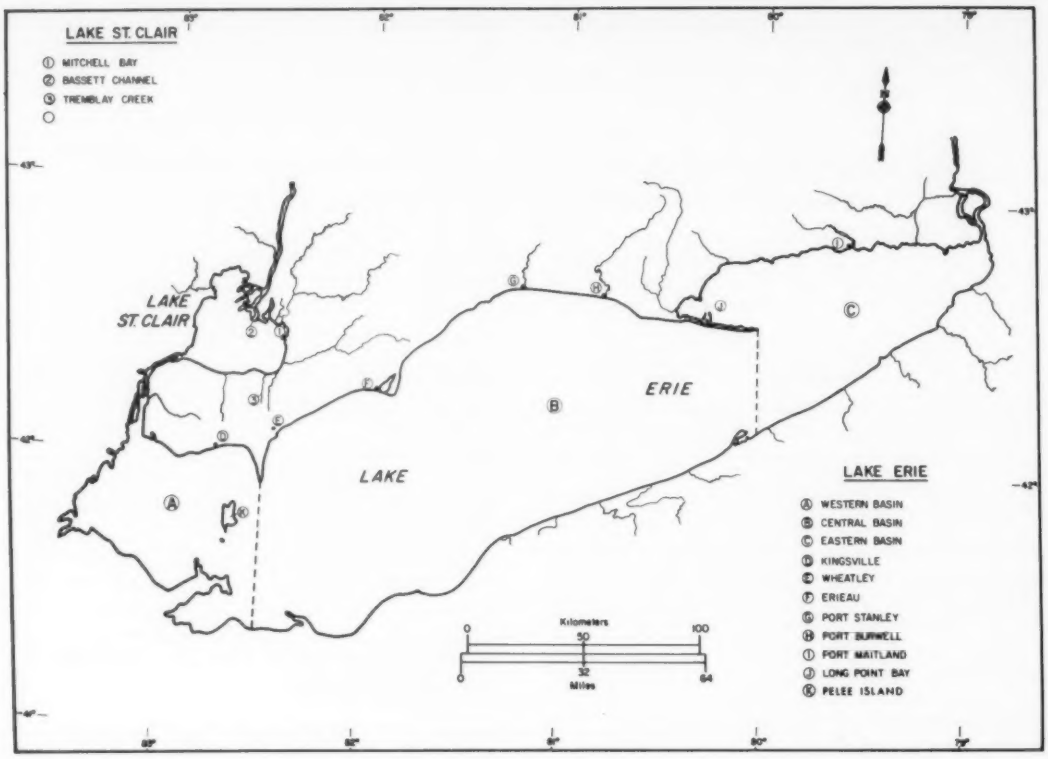


FIGURE 1. *Map of Lakes Erie and Saint Clair showing fish collection areas.*

staff of the Ontario Ministry of Natural Resources. Some of the larger fish were obtained from commercial gill net catches. Eighteen species (278 fish) were caught in Lake Saint Clair in or around Mitchell Bay, Tremblay Creek, and Bassett Channel (Figure 1). Nineteen species (1,023 fish) were caught in Canadian waters of Lake Erie. These came from onshore and offshore locations in all three basins, as defined by Thomas et al. (*16*). Eleven species (429 fish) from the western basin were caught off Kinsville and west of Pelee Island. Nine species (287 fish) were caught in the central basin off Wheatley, Erieau, Port Stanley, and Port Burwell. Fifteen species (307 fish) from the eastern basin were netted in Long Point Bay and off Port Maitland (Figure 1).

Fish species were identified and named according to the nomenclature of the American Fisheries Society (*1*).

### *Analytical Procedure*

Fish were eviscerated, their heads were removed, and the remaining flesh was minced in a Hobart food chopper to a homogeneous consistency from which a representative subsample was selected. Tissue homogenates were stored at −20°C until analysis; storage time rarely exceeded 4 months. Ten grams of tissue homogenate was ground with 100 g anhydrous sodium sulfate and 25 g Ottawa sand. This mixture was extracted in hexane for 7 hours in a Soxhlet extractor. The solvent was removed by rotary vacuum, and the percentage of fat or oil was determined gravimetrically.

TABLE 1. *Analyses of fish caught in Lakes Saint Clair and Erie, 1968–76*

| | Lake Saint Clair | | | Lake Erie | | |
|---|---|---|---|---|---|---|
| Year | Fish Species | Fish Caught | Analyses Performed | Fish Species | Fish Caught | Analyses Performed |
| 1968 | 6 | 25 | 25 | 14 | 115 | 106 |
| 1970 | 6 | 45 | 45 | 1 | 11 | 11 |
| 1971 | 15 | 183 | 183 | 11 | 137 | 119 |
| 1972 | 0 | 0 | 0 | 3 | 78 | 78 |
| 1973 | 0 | 0 | 0 | 1 | 10 | 1 |
| 1974 | 0 | 0 | 0 | 1 | 5 | 5 |
| 1975 | 1 | 6 | 6 | 11 | 636 | 181 |
| 1976 | 2 | 19 | 19 | 3 | 31 | 31 |
| TOTAL | 18 | 278 | 278 | 19 | 1023 | 532 |

NOTE: Purees of eviscerated, headless samples were analyzed.

A one-step Florisil column cleanup method described by Langlois et al. was used to isolate organochlorines and PCBs (*8*). Florisil (60–100 mesh), activated commercially at 650°C, was reheated at 135°C for at least 24

hours; after the adsorbent cooled, it was equilibrated with 5 weight percent water. A maximum of 1 g fat from the fish extracts was thoroughly mixed with 25 g of conditioned Florisil; this was placed on top of a second 25-g portion of conditioned Florisil in a 25-mm ID cleanup column. The column was eluted with 300 ml 1:4 (v/v) mixture of dichloromethane–hexane. The eluate was evaporated to dryness with rotary vacuum, and the residue was dissolved in 5 ml acetone.

PCBs were separated from organochlorine insecticides and HCB on a charcoal column as described by Holdrinet (*6*). Charcoal (Fisher No. 5-690, 50–200 mesh) was washed with acetone, filtered by suction, dried, and stored at 135°C. Columns (9-mm ID) were prepared by sandwiching a 7.5-cm layer of charcoal between 1.3-cm layers of sand and prewashing with a 1:3 (v/v) mixture of acetone–diethyl ether. The acetone solution from the Florisil cleanup was quantitatively transferred to the charcoal column and eluted successively with 180 ml of 1:3 (v/v) mixture of acetone–diethyl ether and 80 ml benzene; the organochlorine insecticides were contained in the first eluate, and PCBs were in the second eluate. Eluates were concentrated to dryness by rotary vacuum and dissolved in measured amounts of hexane.

Extracts were analyzed on a Tracor Model 550 gas chromatograph with the following instrument parameters and operating conditions:

| | |
|---|---|
| Detector: | $^{63}$Ni electron-capture |
| Column: | glass, 15 cm × 0.64 cm OD packed with a mixure of 4 percent SE-30 and 6 percent QF-1 on 80–100-mesh Chromosorb W |
| Temperature: | 180°C |
| Carrier gas: | nitrogen flowing at 60 ml/minute |
| Injection volume: | 5 $\mu$l equivalent to 1 ng fat |

Residue identity was confirmed on random samples by thin-layer chromatography (TLC); appropriate areas of the chromatogram were removed, redissolved, and re-examined by gas-liquid chromatography (GLC). This confirmation was essential for the positive identification of *cis*- and *trans*-chlordane which, when analyzed by GLC alone, are subject to misidentification because of co-extractive interferences.

Recoveries of pesticides and PCBs were checked periodically by fortification of fish tissue homogenate before the Soxhlet extraction. Average recoveries were as follows: *p,p'*-DDT, 89 percent; *p,p'*-DDE, 96 percent; *p,p'*-TDE, 94 percent; *o,p'*-DDT, 91 percent; dieldrin, 89 percent; *cis*-chlordane, 92 percent; *trans*-chlordane, 90 percent; and PCBs, 85–90 percent. The data do not include corrections for recovery. Quantitation limits, below which values were designated as either trace or not detected, were set at 0.005 ppm in fat for all organochlorine insecticides and 0.05 ppm in fat for PCBs.

PCB estimations were based on comparison with standard mixtures of Aroclors 1254 and 1260 and were quantitated by comparison of the sum of peak heights of peaks VII, VIII, and X according to the Reynolds numbering system (*14*). The ratio of Aroclor 1254 to Aroclor 1260 in the standard mixture varied from 5:1 to 4:1.

Analysis began in 1968 when the known main contaminants in fish were *p,p'*-DDT and its analogs and dieldrin and heptachlor epoxide; PCB values before 1970 were estimated. With the introduction of a column fractionation technique in 1970 for the separation of PCBs from organochlorine insecticides, the measurement of PCB residues became more precise. Analysis for hexachlorobenzene (HCB) was included in the procedure in 1973 but was subsequently discontinued because of the low levels and incidence of HCB found in the samples. Analysis and confirmation for *cis*- and *trans*-chlordane was refined in 1975, and the analyses for mirex and oyychlordane were introduced in 1976.

## *Results*

### LAKE SAINT CLAIR

*ΣDDT*—None of the 18 species caught in Lake Saint Clair contained mean residues of ΣDDT that exceeded the 5 ppm action level established by both the Canadian and United States governments. Longnose gar (*Lepisosteus osseus*) caught in 1971 had the highest mean residue of 1.19 ppm and was the only species with a mean residue above 1.0 ppm (Table 2). Eight of 12 longnose gar caught off Tremblay Creek contained ΣDDT residues of 1.10–2.35 ppm. Individual fish from three other species contained residues that exceeded 1.0 ppm. In 1971, two of eight carp (*Cyprinus carpio*) from Mitchell Bay contained 1.19 ppm and 1.26 ppm ΣDDT. Four of 12 mooneye (*Hiodon tergisus*) caught in 1970 off Tremblay Creek had 1.12–2.38 ppm ΣDDT.

Three of six smallmouth bass (*Micropterus dolomieui*) caught in 1975 had ΣDDT residues of 1.02–1.15 ppm.

Eight of the 18 species from Lake Saint Clair were caught in 1968–71. In seven of the species, residues of ΣDDT showed a decline by 1971 (Tables 2, 3). Only quillback (*Carpiodes cyprinus*) showed no apparent change. In all years, however, residues of ΣDDT were below 0.5 ppm.

Smallmouth bass, freshwater drum (*Aplodinotus grunniens*), and walleye (*Stizostedion vitreum vitreum*) were the only three species caught in 1968–71 and again in 1975–76. In smallmouth bass, mean ΣDDT residues were higher in 1976 (0.76 ppm) than in 1968 (0.42 ppm); however, the mean weight of fish was 853 g as opposed to 453 g (Table 2). When residues of similar weight classes were compared, the residue declined slightly between the two periods (Table 3). A mean

TABLE 2. *Organochlorine residues in 18 fish species caught in Canadian waters of Lake Saint Clair, 1968–76*

| Species | Year | No. of Analyses[1] | Mean and Range Weight, g | Mean and Range Fat, % | Mean Content and Range of Contaminants in Fish Puree, ppm[2] DDE | TDE | DDT | ΣDDT | Dieldrin | PCBs |
|---|---|---|---|---|---|---|---|---|---|---|
| *Amiidae* | | | | | | | | | | |
| Bowfin | 1971 | 10 | 1367 | 0.2 | <0.01 | <0.01 | <0.01 | 0.01 | <0.01 | <0.1 |
| | | | 955–2050 | 0.1–0.4 | <0.01–0.01 | | | <0.01–0.02 | | |
| *Catostomidae* | | | | | | | | | | |
| Quillback | 1970 | 6 | 1319 | 4.2 | 0.03 | 0.03 | 0.02 | 0.08 | 0.01 | 0.3 |
| | | | 300–1775 | 1.6–7.6 | 0.01–0.04 | 0.01–0.06 | 0.01–0.03 | 0.03–0.13 | <0.01–0.02 | 0.2–0.4 |
| | 1971 | 9 | 1244 | 2.1 | 0.03 | 0.03 | 0.02 | 0.08 | <0.01 | 0.2 |
| | | | 350–1935 | 1.1–4.5 | <0.01–0.07 | <0.01–0.08 | <0.01–0.06 | 0.02–0.17 | | <0.1–0.3 |
| Redhorse | 1970 | 8 | 928 | 2.6 | 0.07 | 0.03 | 0.03 | 0.13 | 0.01 | 0.7 |
| | | | 695–1235 | 0.3–5.8 | <0.01–0.25 | <0.01–0.11 | <0.01–0.13 | <0.01–0.49 | <0.01–0.04 | <0.1–2.6 |
| | 1971 | 8 | 698 | 0.7 | 0.01 | 0.01 | <0.01 | 0.03 | <0.01 | 0.2 |
| | | | 375–985 | 0.3–1.3 | <0.01–0.03 | <0.01–0.02 | <0.01–0.02 | 0.01–0.07 | | <0.1–0.4 |
| White sucker | 1968 | 2 | 547 | 2.8 | 0.07 | 0.04 | 0.08 | 0.19 | <0.01 | 0.1 |
| | | | 306–787 | 2.2–3.4 | 0.01–0.12 | 0.01–0.07 | 0.02–0.14 | 0.04–0.33 | | <0.1–0.2 |
| | 1970 | 10 | 1298 | 1.3 | 0.01 | 0.02 | 0.01 | 0.04 | <0.01 | 0.3 |
| | | | 1035–2050 | 0.7–2.5 | <0.01–0.03 | <0.01–0.04 | <0.01–0.03 | <0.01–0.06 | | 0.2–0.4 |
| *Centrarchidae* | | | | | | | | | | |
| Largemouth bass | 1970 | 6 | 564 | 3.5 | 0.22 | 0.09 | 0.10 | 0.41 | 0.03 | 1.3 |
| | | | 315–685 | 1.8–7.2 | 0.12–0.40 | 0.04–0.22 | 0.03–0.26 | 0.19–0.88 | <0.01–0.08 | 0.3–4.3 |
| | 1971 | 5 | 632 | 2.6 | 0.18 | 0.07 | 0.06 | 0.31 | 0.02 | 0.8 |
| | | | 250–1100 | 1.4–4.2 | 0.14–0.21 | 0.03–0.13 | 0.02–0.11 | 0.19–0.45 | <0.01–0.04 | 0.6–1.2 |
| Rock bass | 1971 | 10 | 230 | 0.4 | <0.01 | <0.01 | <0.01 | 0.01 | <0.01 | 0.1 |
| | | | 145–335 | 0.1–0.7 | <0.01–0.02 | | <0.01–0.02 | <0.01–0.04 | | <0.1–0.3 |
| Smallmouth bass | 1968 | 5 | 453 | 2.9 | 0.20 | 0.11 | 0.21 | 0.52 | <0.01 | 0.3 |
| | | | 283–748 | 2.0–3.4 | 0.13–0.31 | 0.08–0.18 | 0.14–0.32 | 0.38–0.69 | | 0.2–0.6 |
| | 1975 | 6 | 853 | 2.5 | 0.60 | 0.11 | 0.05 | 0.76 | 0.09 | 2.1 |
| | | | 264–1491 | 1.1–3.6 | 0.09–0.92 | 0.02–0.16 | 0.02–0.09 | 0.13–1.15 | 0.03–0.14 | 0.4–3.1 |
| Bluegill | 1971 | 25 | 172 | 0.4 | <0.01 | <0.01 | <0.01 | 0.01 | <0.01 | <0.1 |
| | | | 85–250 | 0.1–1.8 | <0.01–0.02 | | | <0.01–0.04 | | <0.1–0.2 |
| Black crappie | 1968 | 6 | 174 | 2.3 | 0.08 | 0.05 | 0.10 | 0.23 | <0.01 | 0.2 |
| | | | 116–212 | 0.4–6.2 | 0.03–0.17 | 0.01–0.12 | 0.04–0.71 | 0.11–0.60 | | <0.1–0.5 |
| | 1971 | 13 | 199 | 0.3 | <0.01 | <0.01 | <0.01 | 0.01 | <0.01 | <0.1 |
| | | | 35–455 | 0.2–0.6 | <0.01–0.01 | | | <0.01–0.02 | | <0.1–0.2 |
| Pumpkinseed | 1968 | 5 | 118 | 2.8 | 0.03 | 0.03 | 0.05 | 0.11 | 0.01 | 0.1 |
| | | | 97–137 | 2.3–3.7 | 0.02–0.03 | 0.02–0.04 | 0.04–0.06 | 0.08–0.13 | <0.01–0.02 | <0.1–0.2 |
| | 1971 | 22 | 104 | 0.4 | 0.02 | 0.01 | 0.01 | 0.04 | <0.01 | <0.1 |
| | | | 40–265 | 0.1–0.8 | 0.01–0.02 | 0.01–0.01 | 0.01–0.02 | 0.03–0.05 | <0.01–0.01 | <0.1–0.1 |
| *Cyprinidae* | | | | | | | | | | |
| Carp | 1971 | 8 | 3676 | 10.1 | 0.30 | 0.19 | 0.04 | 0.53 | 0.04 | 0.7 |
| | | | 1410–9710 | 3.1–22.0 | 0.04–0.84 | 0.05–0.53 | <0.01–0.10 | 0.09–1.26 | <0.01–0.13 | 0.3–1.5 |
| *Hiodontidae* | | | | | | | | | | |
| Mooneye | 1970 | 12 | 306 | 10.7 | 0.72 | 0.09 | 0.12 | 0.93 | 0.03 | 1.9 |
| | | | 100–485 | 6.8–14.9 | 0.31–1.20 | 0.05–0.29 | 0.01–0.89 | 0.10–2.38 | 0.01–0.13 | 0.7–7.2 |
| *Ictaluridae* | | | | | | | | | | |
| Brown bullhead | 1971 | 12 | 427 | 0.5 | <0.01 | <0.01 | <0.01 | 0.01 | <0.01 | 0.1 |
| | | | 240–580 | 0.1–1.4 | <0.01–0.02 | | | <0.01–0.03 | | <0.1–0.3 |
| Channel catfish | 1971 | 6 | 2016 | 5.2 | 0.36 | 0.10 | 0.08 | 0.54 | 0.02 | 2.3 |
| | | | 465–5275 | 2.6–10.2 | 0.14–0.75 | 0.03–0.14 | <0.01–0.17 | 0.22–0.89 | <0.01–0.04 | 0.9–3.9 |
| *Lepisosteidae* | | | | | | | | | | |
| Longnose gar | 1971 | 12 | 723 | 3.7 | 0.79 | 0.27 | 0.13 | 1.19 | 0.02 | 1.5 |
| | | | 320–1310 | 0.7–9.1 | 0.28–1.82 | 0.12–0.46 | <0.01–0.21 | 0.48–2.35 | <0.01–0.03 | 0.5–4.0 |
| *Percidae* | | | | | | | | | | |
| Yellow perch | 1968 | 3 | 201 | 1.1 | 0.08 | 0.05 | 0.10 | 0.23 | <0.01 | <0.1 |
| | | | 135–236 | 0.5–1.4 | 0.04–0.16 | 0.02–0.10 | 0.04–0.23 | 0.10–0.49 | | |
| | 1970 | 3 | 108 | 0.4 | 0.02 | <0.01 | <0.01 | 0.03 | <0.01 | 0.1 |
| | | | 80–155 | 0.1–0.7 | <0.01–0.2 | | <0.01–0.01 | <0.01–0.05 | | <0.1–0.2 |
| | 1971 | 11 | 59 | 0.3 | 0.01 | <0.01 | <0.01 | 0.02 | <0.01 | 0.1 |
| | | | 35–75 | 0.1–0.5 | <0.01–0.02 | | <0.01–0.01 | <0.01–0.03 | | <0.1–0.2 |
| Walleye | 1968 | 4 | 410 | 1.1 | 0.08 | 0.04 | 0.08 | 0.20 | <0.01 | <0.1 |
| | | | 250–539 | 0.8–1.3 | 0.02–0.14 | 0.01–0.06 | 0.02–0.14 | 0.05–0.34 | | |
| | 1971 | 20 | 401 | 2.2 | 0.05 | 0.05 | 0.01 | 0.11 | 0.02 | 0.4 |
| | | | 120–1990 | 0.1–5.1 | <0.01–0.17 | <0.01–0.25 | <0.01–0.04 | <0.01–0.42 | <0.01–0.15 | <0.1–2.0 |
| | 1976 | 9 | 1726 | 0.8 | 0.06 | 0.01 | 0.01 | 0.08 | 0.01 | 0.2 |
| | | | 203–3311 | 0.3–2.5 | <0.01–0.21 | ND–0.05 | ND–0.04 | <0.01–0.28 | ND–0.01 | <0.1–0.8 |
| *Sciaenidae* | | | | | | | | | | |
| Freshwater drum | 1971 | 12 | 519 | 1.6 | 0.01 | <0.01 | 0.01 | 0.03 | <0.01 | 0.2 |
| | | | 225–1130 | 0.3–6.1 | <0.01–0.04 | <0.01–0.02 | <0.01–0.05 | <0.01–0.09 | | <0.1–0.6 |
| | 1976 | 10 | 259 | 1.7 | 0.02 | <0.01 | <0.01 | 0.03 | <0.01 | 0.2 |
| | | | 86–521 | 0.6–4.4 | <0.01–0.04 | <0.01–0.02 | ND–0.01 | 0.01–0.05 | | <0.1–0.3 |

NOTE: ND=none detected.
[1] Number of analyses represents number of individual fish (278).
[2] Eviscerated fish with heads and tails removed.

residue of 0.03 ppm ΣDDT was present in freshwater drum caught in 1971 and 1976, and little change occurred among different weight classes (Tables 2, 3). Walleye caught in three separate years had steadily declining ΣDDT residues: 0.20 ppm in 1968, 0.11 ppm in 1971, and 0.08 ppm in 1976. By weight class, a

TABLE 3. *Comparison of residues by weight class of six fish species caught in Lakes Saint Clair and Erie, 1968–76*

| Species | Lake[1] | Year | Weight Class, kg | Number of Analyses[2] | Mean Weight, g | Mean Fat, % | Mean Content of Residues in Tissue, ppm ΣDDT | Dieldrin | PCBs |
|---|---|---|---|---|---|---|---|---|---|
| Smallmouth bass | Saint Clair | 1968 | 0.25–0.50 | 4 | 378 | 2.8 | 0.48 | 0.006 | 0.38 |
| | | | 0.50–0.75 | 1 | 748 | 3.3 | 0.67 | ND | 0.26 |
| | | 1975 | 0.25–0.50 | 1 | 264 | 2.5 | 0.13 | 0.030 | 0.40 |
| | | | 0.50–0.75 | 1 | 698 | 1.1 | 0.28 | 0.030 | 0.90 |
| | | | 0.75–1.00 | 2 | 826 | 3.5 | 0.93 | 0.125 | 2.60 |
| | | | 1.00+ | 2 | 1252 | 2.1 | 1.13 | 0.120 | 3.00 |
| | Erie (E) | 1968 | 0–0.25 | 9 | 206 | 1.6 | 0.52 | 0.004 | 0.28 |
| | | | 0.25–0.50 | 7 | 374 | 2.0 | 1.24 | 0.009 | 0.41 |
| | | 1971 | 1.25–1.50 | 2 | 1449 | 7.5 | 1.20 | 0.002 | 5.80 |
| | | 1972 | 0–0.25 | 8 | 89 | 2.2 | 0.12 | 0.006 | 0.35 |
| | | | 0.25–0.50 | 8 | 412 | 3.5 | 0.25 | 0.019 | 0.86 |
| | | | 0.50–0.75 | 2 | 624 | 4.0 | 0.33 | 0.025 | 1.00 |
| | | 1975 | 0.25–0.50 | 1 | 480 | 3.8 | 0.12 | 0.050 | 0.40 |
| | | | 0.50–0.75 | 1 | 707 | 3.5 | 0.09 | 0.20 | 0.30 |
| | | | 0.75–1.00 | 3 | 838 | 3.9 | 0.15 | 0.027 | 0.30 |
| | | | 1.00+ | 1 | 1226 | 5.4 | 0.30 | 0.020 | 0.40 |
| White bass | Erie (E,W) | 1968 | 0–0.25 | 7 | 127 | 2.7 | 0.32 | 0.010 | 0.06 |
| | | | 0.25–0.50 | 1 | 295 | 2.1 | 1.51 | 0.007 | 0.31 |
| | (E,C,W) | 1971 | 0–0.25 | 29 | 156 | 5.3 | 0.11 | ND | 1.44 |
| | | | 0.25–0.50 | 2 | 388 | 8.0 | 0.15 | ND | 3.10 |
| | (E) | 1972 | 0–0.25 | 27 | 124 | 3.2 | 0.15 | 0.014 | 0.65 |
| | | | 0.25–0.50 | 2 | 361 | 7.2 | 0.55 | 0.025 | 3.30 |
| | | | 0.75–1.00 | 1 | 755 | 9.0 | 0.71 | 0.020 | 4.70 |
| | (C,W) | 1975 | 0–0.25 | 3 | 77 | 7.5 | 0.16 | 0.153 | 0.70 |
| | | | 0.25–0.50 | 1 | 319 | 8.6 | 0.42 | 0.160 | 2.40 |
| | | | 0.50–0.75 | 1 | 607 | 7.3 | 0.56 | 0.190 | 3.20 |
| | (E) | 1976 | 0–0.25 | 6 | 93 | 3.5 | 0.05 | 0.005 | 0.12 |
| | | | 0.25–0.50 | 1 | 274 | 3.8 | 0.06 | 0.006 | 0.10 |
| Freshwater drum | Saint Clair | 1971 | 0–0.25 | 2 | 235 | 1.0 | 0.01 | 0.004 | 0.09 |
| | | | 0.25–0.50 | 5 | 405 | 2.0 | 0.03 | 0.005 | 0.22 |
| | | | 0.50–0.75 | 3 | 560 | 1.1 | 0.02 | 0.002 | 0.13 |
| | | | 1.00–1.25 | 2 | 1023 | 1.9 | 0.05 | 0.004 | 0.21 |
| | | 1976 | 0–0.25 | 4 | 138 | 0.8 | 0.03 | 0.004 | 0.17 |
| | | | 0.25–0.50 | 5 | 303 | 2.3 | 0.03 | 0.004 | 0.17 |
| | | | 0.50–0.75 | 1 | 521 | 1.0 | 0.04 | ND | 0.18 |
| | Erie (W) | 1968 | 0–0.25 | 8 | 120 | 2.6 | 0.23 | 0.005 | 0.05 |
| | | | 0.25–0.50 | 3 | 344 | 2.8 | 0.27 | 0.008 | 0.05 |
| | (E,C,W) | 1971 | 0–0.25 | 18(14) | 144 | 5.9 | 0.03 | ND | 1.75 |
| | | | 0.25–0.50 | 7 | 387 | 9.0 | 0.12 | ND | 2.17 |
| | | | 0.50–0.75 | 3 | 570 | 6.3 | 0.23 | ND | 3.87 |
| | (E,C,W) | 1975 | 0–0.25 | 9(16) | 85 | 3.1 | 0.03 | 0.017 | 0.28 |
| | | | 0.25–0.50 | 13 | 387 | 4.7 | 0.10 | 0.038 | 0.85 |
| | | | 0.50–0.75 | 10 | 606 | 4.9 | 0.17 | 0.036 | 0.57 |
| | | | 0.75–1.00 | 2 | 832 | 3.7 | 0.10 | 0.015 | 0.25 |
| Yellow perch | Saint Clair | 1968 | 0–0.25 | 3 | 201 | 1.1 | 0.24 | 0.003 | 0.09 |
| | | 1970 | 0–0.25 | 3 | 108 | 0.4 | 0.28 | 0.003 | 0.12 |
| | | 1971 | 0–0.25 | 11 | 59 | 0.3 | 0.02 | 0.003 | 0.11 |
| | Erie (C,W) | 1968 | 0–0.25 | 23 | 123 | 1.0 | 0.11 | 0.006 | 0.06 |
| | (E,C,W) | 1971 | 0–0.25 | 29 | 112 | 2.1 | 0.04 | ND | 0.64 |
| | (E) | 1972 | 0–0.25 | 29 | 87 | 2.6 | 0.08 | 0.011 | 0.25 |
| | | | 0.25–0.50 | 1 | 449 | 4.4 | 0.07 | 0.010 | 0.23 |
| | (E,C,W) | 1975 | 0–0.25 | 42(111) | 63 | 1.9 | 0.06 | 0.023 | 0.38 |
| | | | 0.25–0.50 | 2 | 384 | 3.4 | 0.11 | 0.035 | 0.45 |
| | | | 0.50–0.75 | 2 | 594 | 2.9 | 0.06 | 0.035 | 0.30 |
| | (E) | 1976 | 0–0.25 | 15 | 112 | 1.6 | 0.04 | 0.012 | 0.20 |
| Coho salmon | Erie (C) | 1968 | 0–1.0 | 2 | 471 | 5.4 | 0.51 | 0.029 | 0.33 |
| | | 1970 | 1.0–2.0 | 2 | 1795 | 12.6 | 4.53 | 0.100 | 5.80 |
| | | | 2.0–3.0 | 9 | 2263 | 11.6 | 2.40 | 0.080 | 2.10 |
| | (C) | 1971 | 0–1.0 | 3 | 806 | 11.5 | 1.76 | 0.010 | 1.70 |
| | (C,W) | 1975 | 0–1.0 | 1 | 932 | 0.1 | 0.12 | 0.020 | 0.70 |
| | | | 1.0–2.0 | 6 | 1823 | 1.1 | 0.15 | 0.035 | 0.90 |
| | | | 2.0–3.0 | 10 | 2501 | 0.9 | 0.11 | 0.035 | 0.63 |
| | | | 3.0–4.0 | 8 | 3369 | 1.3 | 0.20 | 0.050 | 1.06 |
| | | | 5.0–6.0 | 1 | 5300 | 2.5 | 0.76 | 0.070 | 2.70 |
| | | 1976 | 0–1.0 | 1 | 515 | 1.7 | 0.09 | 0.014 | 0.26 |
| | | | 1.0–2.0 | 1 | 1625 | 2.7 | 0.09 | 0.012 | 0.52 |
| | | | 2.0–3.0 | 3 | 2641 | 1.9 | 0.11 | 0.011 | 0.28 |
| | | | 3.0–4.0 | 1 | 3125 | 1.4 | 0.04 | 0.004 | 0.11 |
| Walleye | Saint Clair | 1968 | 0–0.5 | 3 | 366 | 1.1 | 0.14 | 0.004 | 0.07 |
| | | | 0.5–1.0 | 1 | 539 | 1.2 | 0.34 | 0.004 | 0.12 |
| | | 1971 | 0–0.5 | 15 | 225 | 2.6 | 0.13 | 0.026 | 0.50 |
| | | | 0.5–1.0 | 4 | 660 | 0.7 | 0.02 | 0.001 | 0.13 |
| | | | 1.5–2.0 | 1 | 1990 | 1.2 | 0.06 | 0.003 | 0.17 |
| | | 1976 | 0–0.5 | 1 | 203 | 2.5 | 0.18 | 0.011 | 0.75 |
| | | | 0.5–1.0 | 2 | 678 | 0.8 | 0.04 | ND | 0.11 |
| | | | 1.5–2.0 | 3 | 1690 | 0.3 | 0.02 | ND | 0.09 |
| | | | 2.0–2.5 | 1 | 2496 | 0.7 | 0.12 | 0.008 | 0.28 |
| | | | 3.0–3.5 | 2 | 3204 | 0.8 | 0.15 | 0.055 | 0.32 |

*(Continued next page)*

TABLE 3 (cont'd.). *Comparison of residues by weight class of six fish species caught in Lakes Saint Clair and Erie, 1968–76*

| Species | Lake[1] | Year | Weight Class, kg | Number of Analyses[2] | Mean Weight, g | Mean Fat, % | Mean Content of Residues in Tissue, ppm ΣDDT | Dieldrin | PCBs |
|---|---|---|---|---|---|---|---|---|---|
| | Erie | | | | | | | | |
| | (W) | 1968 | 0–0.5 | 3 | 265 | 2.1 | 0.24 | 0.005 | 0.08 |
| | | | 0.5–1.0 | 3 | 773 | 3.7 | 0.42 | 0.010 | 0.24 |
| | (E,W) | 1971 | 0–0.5 | 4 | 369 | 3.7 | 0.04 | ND | 0.89 |
| | | | 0.5–1.0 | 1 | 725 | 3.0 | 0.02 | ND | 1.10 |
| | (W) | 1975 | 0–0.5 | 1(5) | 72 | 3.7 | 0.13 | 0.054 | 0.66 |
| | | | 0.5–1.0 | 1 | 906 | 3.9 | 0.15 | 0.060 | 0.70 |
| | | | 2.0–2.5 | 2 | 2175 | 21.3 | 1.32 | 0.360 | 4.60 |

[1] E=eastern basin; C=central basin; W=western basin.
[2] Analyses performed on single fish in most cases; in some cases composite samples were analyzed, and the number of fish is in parentheses.

marked drop was noted for ΣDDT between 1968 and 1971, but thereafter the decline was small (Tables 2, 3).

*Dieldrin*—Mean residues in all species were less than 0.10 ppm. In addition, 12 species had mean residues at or below 0.01 ppm dieldrin. The highest mean residue of 0.09 ppm was present in smallmouth bass caught in 1975 (Table 2). By weight class, smallmouth bass exhibited an increase in dieldrin residues between 1968 and 1976 (Table 3). Only three other species, carp, mooneye, and walleye, had individual fish with residues of 0.10–0.15 ppm dieldrin (Table 2). Dieldrin residues in walleye peaked in 1971 and declined by 1976 (Table 3). Freshwater drum, the only other species caught in the early and late years, showed no change in dieldrin residues (Tables 2, 3).

*PCBs*—Only one fish from Lake Saint Clair, a 435-g mooneye, exceeded the 5.0 ppm tolerance level for PCB residues in fish tissues set by the Food and Drug Administration, U.S. Department of Health, Education, and Welfare. However, several species and individual fish exceeded the 2.0 ppm Health and Welfare Canada tolerance level (Table 2). Smallmouth bass caught in 1975 and channel catfish caught in 1971 had mean residues of 2.1 ppm and 2.3 ppm PCBs, respectively (Table 2). In 1970, one of six largemouth bass (*Micropterus salmoides*), four of 12 mooneye, and one of eight redhorse (*Moxostoma* sp.) contained 2.1–7.2 ppm PCBs. In 1971, three of 11 longnose gar, and four of six channel catfish caught in Tremblay Creek and in Mitchell Bay, respectively, had residues of 2.0–4.0 ppm PCBs. In 1975, PCB levels in four of six smallmouth bass ranged from 2.2 to 3.1 ppm.

PCB residues increased in smallmouth bass between 1968 and 1975. However, freshwater drum and walleye showed little change even by weight class (Tables 2, 3).

*HCB*—Forty-eight fish of 17 species caught in 1970–71 and analyzed in 1973 had detectable HCB residues below 0.1 ppm. Redhorse mullet had the highest mean residue, 0.024 ppm, and the highest residue in a single fish, 0.08 ppm. Carp, channel catfish, and yellow perch (*Perca flavescens*) had the second highest residues of 0.013 ppm HCB (Table 4).

*Chlordane and heptachlor epoxide*—The same 48 fish caught in 1970–71 were analyzed for *cis*- and *trans*-chlordane and heptachlor epoxide. Interfering compounds prevented confirmation of chlordane below 0.05 ppm. Smallmouth bass caught in 1975 contained low levels of chlordane but these could not be satisfactorily separated from interfering compounds. By 1976, both chlordane and heptachlor epoxide were identified at low levels in freshwater drum and walleye (Table 5).

TABLE 4. *Hexachlorobenzene residues in 17 species of fish (48 fish) caught in Lake Saint Clair, 1970–71*

| Fish Species | Year | No. of Fish | Average Weight, g | HCB, ppm Mean | HCB, ppm Range | Location |
|---|---|---|---|---|---|---|
| Largemouth bass | 1970–71 | 2 | 683 | 0.005 | 0.002–0.008 | Mitchell Bay |
| Rock bass | 1971 | 3 | 220 | 0.008 | 0.002–0.013 | Tremblay Creek |
| Bluegill | 1971 | 6 | 170 | 0.002 | <0.001–0.004 | Mitchell Bay |
| Bowfin | 1971 | 2 | 1630 | 0.008 | 0.005–0.015 | Mitchell Bay |
| Brown bullhead | 1971 | 3 | 412 | 0.003 | 0.002–0.003 | Mitchell Bay |
| Carp | 1971 | 2 | 2890 | 0.013 | 0.006–0.020 | Mitchell Bay |
| Channel catfish | 1971 | 2 | 1910 | 0.013 | 0.005–0.020 | Tremblay Creek, Mitchell Bay |
| Black crappie | 1971 | 3 | 243 | 0.002 | 0.001–0.003 | Mitchell Bay |
| Freshwater drum | 1971 | 3 | 623 | 0.006 | 0.002–0.008 | St. Lukes Bay |
| Longnose gar | 1970 | 1 | 1195 | 0.007 | | Tremblay Creek |
| Mooneye | 1970 | 2 | 158 | 0.009 | | Tremblay Creek |
| Yellow perch | 1971 | 2 | 55 | 0.013 | 0.007–0.019 | Mitchell Bay |
| Pumpkinseed | 1971 | 5 | 123 | 0.001 | <0.001–0.002 | Mitchell Bay |
| Quillback | 1970–71 | 4 | 1670 | 0.008 | 0.005–0.010 | Mitchell Bay |
| Redhorse mullet | 1970–71 | 4 | 670 | 0.024 | 0.002–0.080 | Bassett Channel, Mitchell Bay |
| White sucker | 1970 | 3 | 1185 | 0.004 | 0.003–0.006 | Bassett Channel |
| Walleye | 1971 | 1 | 120 | 0.002 | | Mitchell Bay |

TABLE 5. *Chlordane and heptachlor epoxide residues in fish species caught in Lakes Saint Clair and Erie, 1972–76*

| Lake | Fish Species | Year | No. of Fish[1] | Mean Weight, g | Mean Fat, % | Mean Content of Residues in Fish Tissues, ppm Chlordane[2] | Heptachlor Epoxide |
|---|---|---|---|---|---|---|---|
| Saint Clair | Freshwater drum | 1976 | 10 | 259 | 1.7 | 0.011<br>ND–0.080 | 0.003<br>ND–0.013 |
| | Walleye | 1976 | 9 | 1726 | 0.8 | 0.008<br>ND–0.028 | 0.004<br>ND–0.013 |
| Lake Erie | | | | | | | |
| Central basin | Rainbow trout[3] | 1974 | 5 | 642 | 4.4 | ND | 0.006<br>ND–0.033 |
| Eastern basin | White bass | 1972 | 11 | 156 | 5.9 | 0.023<br>0.010–0.050 | ND |
| | | 1976 | 7 | 118 | 3.6 | 0.010<br>0.008–0.011 | 0.004<br>0.002–0.007 |
| | Yellow perch | 1972 | 10 | 133 | 3.2 | 0.011<br><0.001–0.020 | ND |
| | | 1975 | 15 | 60 | 2.1 | 0.007<br>0.002–0.016 | 0.001<br>ND–0.006 |
| | | 1976 | 15 | 121 | 1.6 | 0.007<br><0.001–0.014 | 0.003<br><0.001–0.007 |
| | Coho salmon | 1976 | 6 | 2198 | 11.5 | 0.037<br>0.011–0.045 | 0.007<br>0.002–0.010 |
| | Emerald shiner | 1976 | 4(12) | 5.6 | 5.6 | 0.038<br>0.011–0.050 | 0.012<br>0.006–0.016 |
| | Rainbow smelt | 1975 | 5 | 74 | 8.9 | 0.015<br>0.004–0.021 | 0.006<br>0.001–0.009 |
| | | 1976 | 10 | 20 | 5.1 | 0.046<br>0.022–0.134 | 0.015<br>0.009–0.033 |

[1] See footnote 1, Table 3.
[2] NOTE: Chlordane present as *cis*- and *trans*-isomers in all species except white bass and yellow perch caught in 1972. Then, only *cis*-chlordane was confirmed.
[3] Three rainbow trout caught in Silver Creek also contained endosulfan with mean residue of 0.025 ppm (0.007–0.050 ppm). NOTE: ND=not detected.

*Other organochlorines*—No endrin or methoxychlor was detected in fish caught in Lake Saint Clair. Samples were analyzed for mirex in 1975–76, but no residues were detected in smallmouth bass, freshwater drum, or walleye caught in those years.

LAKE ERIE

*ΣDDT*—No mean residues of ΣDDT for any species caught in Lake Erie in 1968–76 exceeded the 5.0 ppm United States and Canadian tolerance levels. Three coho salmon caught in 1970 in the central basin contained levels of 8.23, 7.67, and 7.61 ppm ΣDDT, and the whole catch of 11 fish averaged 2.80 ppm (Table 6). These three fish were the largest, weighing 1,963, 2,276, and 2,640 g, respectively. Three coho salmon caught in 1971 from the same basin and weighing an average of 806 g contained only 1.76 ppm ΣDDT.

Smallmouth bass caught in 1971 from the eastern basin was the only other species with mean residues above 1.0 ppm; mean residues were 1.2 ppm ΣDDT. Smallmouth bass caught in 1968 from the same basin averaged 0.83 ppm; however, two of 16 fish had 1.53 ppm and 4.28 ppm ΣDDT. White bass and walleye had individual fish with residues above 1.0 ppm.

Five species were caught in all three basins during the same year, and one of these, coho salmon, was caught in three basins over two years (Tables 3, 6, 7). Emerald shiner (*Notropis atherinoides*) and yellow perch, which are localized species, contained residues of ΣDDT that were not significantly different among the three basins. In migrating species of white bass, freshwater drum, coho salmon, and rainbow smelt (*Osmerus mordax*), ΣDDT residues were similar for catches in the three basins. Where differences occurred, the higher residues correlated with fish size rather than with basin. The highest residues of ΣDDT from the central, eastern, and western basins, respectively, were freshwater drum caught in 1971 and 1975 and coho salmon caught in 1975. In all three cases, the individual fish were 1.5–4 times heavier than members of the same species from the other basins, and a correlation was evident between increasing weight and increasing ΣDDT residue; these differences virtually disappear when similar weight classes are compared among the basins (Tables 3, 6, 7).

Six species were divided into weight classes to determine the extent of decline in ΣDDT residues between 1968 and 1976 (Tables 3, 7). In the eastern basin, smallmouth bass, which were caught in four separate years, offered the best example. ΣDDT mean residues for the species peaked in 1971 and declined thereafter (Table 6); when compared by weight class, however, species showed a decline in ΣDDT from 1968 to 1976 (Table 3). Declining residues of ΣDDT in the eastern basin were evident in rock bass (*Ambloplites rupestris*), white bass, and yellow perch but not in rainbow smelt or freshwater drum (Tables 3, 6).

In the central basin, ΣDDT residues in coho salmon peaked in 1971 and declined thereafter. Residues also declined in freshwater drum and rainbow smelt but not

TABLE 6. *Organochlorine residues in 19 fish species caught in Canadian waters of Lake Erie (1968–76) and segregated into western, central, and eastern basins*

| Fish Species | Year | Basin | No. of Analyses[1] | Mean and Range Weight, g | Mean and Range Fat, % | Mean Content and Range of Contaminants in Fish Tissue, ppm DDE | TDE | DDT | ΣDDT | Dieldrin | PCBs |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Centrachidae* | | | | | | | | | | | |
| Largemouth bass | 1975 | East | 12 | 409 | 3.9 | 0.13 | 0.04 | <0.01 | 0.18 | 0.02 | 0.1 |
| | | | | 254–835 | 2.3–7.1 | 0.03–0.33 | 0.01–0.14 | <0.01–0.03 | 0.07–0.50 | <0.01–0.08 | 0.1–0.3 |
| Rock bass | 1968 | East | 7 | 91 | 1.7 | 0.06 | 0.03 | 0.03 | 0.12 | 0.01 | 0.2 |
| | | | | 84–113 | 0.8–2.6 | 0.01–0.14 | <0.01–0.07 | <0.01–0.07 | 0.02–0.28 | <0.01–0.02 | <0.1–0.5 |
| | 1971 | East | 8 | 180 | 1.9 | 0.09 | ND | ND | 0.09 | ND | 0.3 |
| | | | | 101–239 | 1.2–2.7 | 0.02–0.13 | | | 0.02–0.13 | | 0.2–0.6 |
| Smallmouth bass | 1968 | East | 16 | 280 | 1.8 | 0.31 | 0.11 | 0.41 | 0.83 | <0.01 | 0.3 |
| | | | | 162–478 | 0.9–4.2 | 0.11–1.60 | 0.04–0.44 | 0.15–2.24 | 0.32–4.28 | <0.01–0.03 | 0.2–0.84 |
| | 1971 | East | 2 | 1449 | 7.5 | 0.90 | 0.13 | 0.17 | 1.20 | <0.01 | 5.8 |
| | | | | 1376–1522 | 5.7–9.3 | 0.50–1.30 | 0.03–0.23 | 0.05–0.28 | 0.55–1.81 | | 2.3–9.3 |
| | 1972 | East | 18 | 292 | 3.0 | 0.12 | 0.03 | 0.05 | 0.20 | 0.01 | 0.7 |
| | | | | 76–697 | 1.9–5.0 | 0.07–0.27 | 0.01–0.07 | 0.01–0.13 | 0.01–0.42 | <0.01–0.03 | 0.4–1.2 |
| | 1975 | East | 6 | 821 | 4.1 | 0.11 | 0.03 | 0.02 | 0.16 | 0.03 | 0.3 |
| | | | | 480–1226 | 2.5–5.4 | 0.04–0.20 | 0.01–0.25 | <0.01–0.05 | 0.05–0.30 | 0.01–0.05 | 0.2–0.4 |
| Bluegill | 1968 | East | 4 | 209 | 0.5 | <0.01 | <0.01 | <0.01 | 0.02 | <0.01 | <0.1 |
| | | | | 97–341 | 0.4–0.5 | <0.01–0.03 | <0.01–0.01 | <0.01–0.02 | <0.01–0.06 | | |
| Black crappie | 1968 | East | 5 | 111 | 1.2 | 0.06 | 0.04 | 0.04 | 0.14 | <0.01 | <0.1 |
| | | | | 80–173 | 0.7–1.8 | 0.02–0.10 | 0.02–0.07 | 0.01–0.07 | 0.05–0.21 | | <0.1–0.1 |
| Pumpkinseed | 1968 | East | 6 | 95 | 1.4 | 0.02 | 0.01 | 0.01 | 0.04 | <0.01 | <0.1 |
| | | | | 79–113 | 0.9–1.9 | 0.01–0.02 | <0.01–0.01 | | 0.03–0.05 | <0.01–0.01 | <0.1–0.1 |
| *Clupeidae* | | | | | | | | | | | |
| Alewife | 1971 | East | 7 | 101 | 23.2 | 0.24 | ND | ND | 0.24 | <0.01 | 3.0 |
| | | | | 93–108 | 19.4–25.5 | 0.12–0.29 | | | 0.12–0.29 | | 1.9–3.7 |
| | 1975 | West | 2(21) | 40 | 8.6 | 0.05 | 0.08 | ND | 0.13 | 0.07 | 0.5 |
| | | | | 34–51 | 8.1–8.9 | 0.04–0.06 | 0.07–0.09 | | 0.11–0.15 | | 0.4–0.5 |
| | | Central | 5(22) | 39 | 21.8 | 0.05 | 0.09 | ND | 0.14 | 0.08 | 0.4 |
| | | | | 20–66 | 14.1–31.9 | 0.03–0.07 | 0.03–0.15 | | 0.06–0.22 | 0.02–0.15 | 0.3–0.4 |
| Gizzard shad | 1968 | West | 6 | 234 | 9.4 | 0.06 | 0.17 | 0.09 | 0.32 | 0.02 | 0.3 |
| | | | | 37–302 | 4.4–12.6 | 0.04–0.08 | 0.10–0.25 | 0.06–0.15 | 0.20–0.47 | <0.01–0.04 | <0.1–0.6 |
| | 1971 | West | 3(6) | 92 | 15.5 | 0.07 | ND | ND | 0.07 | ND | 2.6 |
| | | | | 74–105 | 13.8–16.7 | 0.06–0.07 | | | 0.06–0.07 | | 2.1–3.5 |
| | | Central | 3(9) | 72 | 15.3 | 0.14 | ND | ND | 0.14 | ND | 3.4 |
| | | | | 67–77 | 11.8–18.6 | 0.08–0.19 | | | 0.08–0.19 | | 2.4–4.7 |
| | 1975 | West | 4(27) | 136 | 11.1 | 0.04 | 0.09 | ND | 0.13 | 0.08 | 0.7 |
| | | | | 110–157 | 10.1–12.0 | 0.03–0.06 | 0.06–0.11 | | 0.09–0.17 | 0.06–0.10 | 0.6–0.9 |
| | | Central | 2(7) | 63 | 12.0 | 0.05 | 0.09 | ND | 0.14 | 0.08 | 0.5 |
| | | | | 47–69 | 4.7–12.6 | | 0.09–0.10 | | 0.14–0.15 | 0.07–0.09 | 0.4–0.6 |
| *Cyprinidae* | | | | | | | | | | | |
| Emerald shiner | 1975 | West | 3(60) | 4.2 | 6.7 | 0.06 | 0.06 | ND | 0.12 | 0.05 | 0.6 |
| | | | | 4.0–4.5 | 5.6–7.7 | 0.05–0.07 | 0.05–0.07 | | 0.10–0.14 | 0.05–0.06 | 0.5–0.7 |
| | | Central | 3(60) | 6.4 | 7.7 | 0.04 | 0.05 | ND | 0.09 | 0.04 | 0.3 |
| | | | | 4.5–8.9 | 5.3–9.0 | 0.03–0.05 | 0.04–0.08 | | 0.07–0.13 | 0.03–0.06 | |
| | | East | 4(12) | 5.6 | 5.6 | 0.08 | 0.02 | 0.02 | 0.12 | 0.02 | 0.4 |
| | | | | 2.5–10.0 | 4.0–8.0 | 0.07–0.10 | 0.01–0.04 | 0.01–0.02 | 0.10–0.16 | ND–0.03 | 0.3–0.6 |
| Spottail shiner | 1975 | West | 3(60) | 11.1 | 3.8 | 0.05 | 0.06 | ND | 0.11 | 0.04 | 0.06 |
| | | | | 5.7–16.0 | 3.5–4.0 | 0.03–0.07 | 0.04–0.08 | | 0.07–0.15 | 0.03–0.06 | 0.04–0.07 |
| *Ictaluridae* | | | | | | | | | | | |
| Brown bullhead | 1968 | East | 4 | 149 | 0.9 | 0.02 | 0.02 | 0.01 | 0.05 | <0.01 | <0.1 |
| | | | | 95–183 | 0.2–1.4 | <0.01–0.04 | <0.01–0.03 | <0.01–0.02 | 0.01–0.10 | | |
| Channel catfish | 1968 | West | 4 | 105 | 3.5 | 0.13 | 0.18 | 0.15 | 0.46 | 0.01 | 0.2 |
| | | | | 74–135 | 2.1–4.5 | 0.09–0.18 | 0.13–0.26 | 0.12–0.20 | 0.34–0.64 | <0.01–0.01 | <0.1–0.2 |
| | 1971 | West | 2 | 518 | 19.3 | 0.16 | ND | ND | 0.16 | ND | 5.0 |
| | | | | 356–680 | 17.7–20.9 | 0.14–0.18 | | | 0.14–0.18 | | 4.2–5.7 |
| Rainbow smelt | 1968 | Central | 4(13) | 24 | 2.2 | 0.05 | 0.04 | 0.09 | 0.18 | 0.01 | 0.2 |
| | | | | 16–30 | 1.7–3.5 | 0.03–0.07 | 0.03–0.06 | 0.07–0.10 | 0.13–0.22 | <0.01–0.02 | 0.2–0.3 |
| | 1971 | East | 2(7) | 36 | 5.9 | 0.09 | ND | ND | 0.09 | ND | 1.3 |
| | | | | 33–41 | 3.8–7.5 | 0.07–0.12 | | | 0.07–0.12 | | 1.2–1.4 |
| | 1973 | West | 1(10) | 26 | 1.1 | 0.13 | 0.14 | 0.04 | 0.31 | 0.06 | 0.5 |
| | 1975 | West | 9(60) | 29 | 3.4 | 0.04 | 0.04 | ND | 0.08 | 0.03 | 0.4 |
| | | | | 22–45 | 3.0–4.4 | 0.02–0.07 | 0.04–0.08 | | 0.05–0.15 | 0.02–0.06 | 0.2–0.6 |
| | | Central | 6(70) | 16 | 3.5 | 0.03 | 0.03 | ND | 0.06 | 0.03 | 0.1 |
| | | | | 13–20 | 3.1–3.8 | 0.02–0.05 | 0.03–0.04 | | 0.05–0.08 | 0.02–0.03 | |
| | | East | 8(23) | 16 | 3.2 | 0.05 | 0.04 | <0.01 | 0.10 | 0.03 | 0.3 |
| | | | | 13–18 | 2.1–4.1 | 0.02–0.08 | 0.01–0.06 | ND–0.03 | 0.03–0.12 | 0.01–0.06 | 0.1–0.6 |
| | 1976 | East | 10 | 30 | 5.1 | 0.05 | 0.04 | 0.02 | 0.11 | 0.05 | 0.3 |
| | | | | 23–55 | 3.4–10.4 | 0.02–0.19 | 0.02–0.16 | <0.01–0.13 | 0.05–0.48 | 0.03–0.10 | <0.1–1.4 |
| *Percidae* | | | | | | | | | | | |
| Yellow perch | 1968 | West | 12 | 141 | 1.3 | 0.04 | 0.06 | 0.04 | 0.14 | <0.01 | <0.1 |
| | | | | 105–216 | 0.4–3.4 | 0.01–0.11 | 0.01–0.14 | 0.01–0.11 | 0.06–0.36 | | |
| | | East | 11 | 108 | 0.8 | 0.03 | 0.02 | 0.05 | 0.10 | <0.01 | <0.1 |
| | | | | 87–137 | 0.5–1.8 | <0.01–0.06 | <0.01–0.05 | 0.02–0.08 | 0.03–0.16 | | <0.1–0.1 |
| | 1971 | West | 10 | 116 | 2.0 | 0.02 | ND | ND | 0.02 | ND | 1.0 |
| | | | | 82–137 | 1.4–2.9 | <0.01–0.06 | | | <0.01–0.06 | | 0.2–2.6 |
| | | Central | 10 | 102 | 1.7 | 0.03 | ND | ND | 0.03 | ND | 0.3 |
| | | | | 79–139 | 1.3–2.7 | 0.02–0.04 | | | 0.02–0.04 | | 0.2–0.6 |
| | | East | 9 | 122 | 2.7 | 0.08 | ND | ND | 0.08 | ND | 0.6 |
| | | | | 99–137 | 1.5–5.8 | 0.04–0.14 | | | 0.04–0.14 | | 0.3–1.0 |

*(Continued next page)*

TABLE 6 (cont'd.). *Organochlorine residues in 19 fish species caught in Canadian waters of Lake Erie (1968–76) and segregated into western, central, and eastern basins*

| Fish Species | Year | Basin | No. of Analyses[1] | Mean and Range Weight, g | Mean and Range Fat, % | Mean Content and Range of Contaminants in Fish Tissue, ppm DDE | TDE | DDT | ΣDDT | Dieldrin | PCBs |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1972 | East | 30 | 98 | 2.6 | 0.06 | 0.01 | 0.01 | 0.08 | 0.01 | 0.3 |
| | | | | 39–449 | 1.0–5.8 | 0.03–0.10 | <0.01–0.03 | <0.01–0.03 | 0.04–0.15 | <0.01–0.03 | 0.1–0.4 |
| | 1975 | West | 10(59) | 40 | 1.7 | 0.03 | 0.04 | ND | 0.07 | 0.03 | 0.6 |
| | | | | 7–84 | 1.4–2.0 | 0.01–0.07 | 0.02–0.07 | | 0.03–0.14 | 0.02–0.07 | 0.4–0.9 |
| | 1975 | Central | 15(30) | 118 | 2.9 | 0.02 | 0.02 | <0.01 | 0.05 | 0.02 | 0.2 |
| | | | | 32–605 | 0.8–3.9 | <0.01–0.05 | ND–0.07 | ND–<0.01 | <0.01–0.11 | ND–0.05 | <0.1–0.8 |
| | | East | 21(26) | 85 | 2.6 | 0.03 | <0.01 | <0.01 | 0.05 | <0.01 | 0.1 |
| | | | | 32–210 | 0.8–3.9 | <0.01–0.13 | ND–0.03 | ND–0.01 | <0.01–0.15 | ND–0.02 | 0.1–0.8 |
| | 1976 | East | 15 | 121 | 1.6 | 0.02 | 0.01 | <0.01 | 0.04 | 0.01 | 0.2 |
| | | | | 69–212 | 0.6–3.5 | 0.01–0.04 | <0.01–0.03 | ND–0.01 | 0.02–0.07 | <0.01–0.03 | <0.1–0.8 |
| Walleye | 1968 | West | 6 | 519 | 2.9 | 0.11 | 0.12 | 0.10 | 0.33 | <0.01 | 0.2 |
| | | | | 256–923 | 1.7–4.1 | 0.06–0.16 | 0.07–0.21 | 0.06–0.15 | 0.19–0.46 | <0.01–0.2 | <0.1–0.3 |
| | 1971 | West | 4 | 460 | 4.0 | 0.03 | ND | ND | 0.03 | ND | 1.0 |
| | | | | 158–362 | 1.9–5.4 | 0.02–0.03 | | | 0.02–0.03 | | 0.5–1.6 |
| | | East | 1 | 362 | 1.9 | 0.06 | ND | ND | 0.06 | ND | 0.6 |
| | 1975 | West | 8(14) | 430 | 6.1 | 0.15 | 0.12 | 0.02 | 0.29 | 0.10 | 1.3 |
| | | | | 57–2275 | 1.8–22.2 | 0.05–0.99 | 0.05–0.66 | <0.01–0.19 | 0.10–1.84 | 0.03–0.45 | 0.3–5.1 |
| *Salmonidae* | | | | | | | | | | | |
| Coho salmon | 1968 | Central | 2 | 471 | 5.4 | 0.19 | 0.12 | 0.20 | 0.51 | 0.03 | 0.3 |
| | | | | 410–531 | 4.0–6.8 | 0.17–0.20 | 0.10–0.14 | 0.18–0.22 | 0.49–0.53 | 0.02–0.04 | 0.2–0.4 |
| | 1970 | Central | 11 | 2178 | 11.8 | 1.05 | 0.92 | 0.83 | 2.80 | 0.09 | 4.0 |
| | | | | 1627–2640 | 9.7–13.6 | 0.31–3.16 | 0.25–2.70 | 0.21–2.37 | 0.77–8.23 | 0.03–0.20 | 1.0–14.0 |
| | 1971 | Central | 3 | 806 | 11.5 | 0.81 | 0.53 | 0.42 | 1.76 | 0.01 | 1.7 |
| | | | | 748–908 | 11.0–12.1 | 0.77–0.85 | 0.24–0.74 | 0.36–0.45 | 1.45–1.99 | 0.01–0.02 | 1.5–2.0 |
| | 1975 | West | 9 | 3081 | 2.7 | 0.24 | 0.10 | ND | 0.34 | 0.08 | 1.4 |
| | | | | 1798–5300 | 0.6–4.9 | 0.08–0.73 | 0.02–0.15 | | 0.10–0.76 | 0.02–0.12 | 0.6–2.7 |
| | | Central | 17 | 2436 | 0.3 | 0.09 | 0.02 | ND | 0.11 | 0.02 | 0.7 |
| | | | | 1773–3520 | 0.1–1.0 | 0.05–0.21 | <0.01–0.10 | | 0.06–0.30 | 0.01–0.07 | 0.4–2.0 |
| | 1976 | East | 6 | 2198 | 1.9 | 0.05 | 0.02 | 0.02 | 0.09 | 0.01 | 0.3 |
| | | | | 515–3125 | 1.3–2.7 | 0.03–0.07 | 0.01–0.03 | <0.01–0.03 | 0.04–0.13 | <0.01–0.02 | 0.1–0.5 |
| Rainbow trout | 1974 | Central | 5 | 642 | 4.3 | 0.13 | 0.06 | <0.01 | 0.20 | 0.07 | 0.3 |
| | | | | 93–1691 | 2.7–6.1 | 0.02–0.43 | <0.01–0.26 | | 0.03–0.69 | <0.01–0.26 | <0.1–0.8 |
| *Sciaenidae* | | | | | | | | | | | |
| Freshwater drum | 1968 | West | 11 | 181 | 2.7 | 0.05 | 0.10 | 0.07 | 0.22 | <0.01 | <0.1 |
| | | | | 41–380 | 0.5–6.4 | 0.03–0.11 | 0.05–0.17 | 0.04–0.11 | 0.12–0.38 | <0.01–0.01 | |
| | 1971 | West | 5(9) | 106 | 5.8 | 0.04 | ND | ND | 0.04 | ND | 1.4 |
| | | | | 82–208 | 3.8–7.3 | 0.01–0.12 | | | 0.01–0.12 | | 0.7–3.5 |
| | | Central | 9 | 407 | 7.8 | 0.17 | ND | ND | 0.17 | ND | 3.7 |
| | | | | 173–688 | 3.8–11.2 | 0.07–0.39 | | | 0.07–0.39 | | 2.2–4.7 |
| | | East | 10 | 239 | 7.3 | 0.03 | ND | ND | 0.03 | ND | 1.3 |
| | | | | 139–390 | 5.5–10.2 | <0.01–0.07 | | | <0.01–0.07 | | 0.6–1.8 |
| | 1975 | West | 16(23) | 255 | 4.4 | 0.03 | 0.03 | ND | 0.06 | 0.03 | 0.6 |
| | | | | 14–674 | 1.5–8.3 | 0.01–0.07 | <0.01–0.07 | | 0.02–0.14 | 0.01–0.07 | 0.2–1.8 |
| | | Central | 8 | 345 | 5.5 | 0.05 | 0.06 | ND | 0.11 | 0.05 | 0.7 |
| | | | | 123–575 | 2.1–9.1 | 0.02–0.12 | 0.04–0.10 | | 0.07–0.19 | 0.03–0.08 | 0.4–1.4 |
| | | East | 10 | 612 | 4.3 | 0.12 | 0.03 | 0.01 | 0.16 | 0.03 | 0.4 |
| | | | | 399–856 | 1.9–7.2 | 0.06–0.30 | <0.01–0.09 | <0.01–0.05 | 0.06–0.42 | 0.01–0.04 | 0.2–0.6 |
| *Serranidae* | | | | | | | | | | | |
| White bass | 1968 | West | 6 | 161 | 3.0 | 0.17 | 0.24 | 0.16 | 0.57 | <0.01 | 0.1 |
| | | | | 117–295 | 2.1–4.2 | 0.04–0.41 | 0.12–0.60 | 0.08–0.40 | 0.23–1.41 | | <0.1–0.3 |
| | | East | 2 | 110 | 1.3 | 0.04 | 0.02 | 0.12 | 0.18 | 0.02 | <0.1 |
| | | | | 107–113 | 1.2–1.5 | 0.03–0.05 | 0.01–0.02 | 0.07–0.16 | 0.11–0.23 | 0.01–0.02 | |
| | 1971 | West | 10 | 230 | 6.5 | 0.09 | ND | ND | 0.09 | ND | 2.2 |
| | | | | 163–401 | 3.2–10.0 | 0.03–0.19 | | | 0.03–0.19 | | 1.1–4.8 |
| | | Central | 11 | 160 | 6.5 | 0.13 | ND | ND | 0.13 | ND | 1.6 |
| | | | | 110–232 | 4.3–11.2 | 0.10–0.17 | | | 0.10–0.17 | | 0.9–2.2 |
| | | East | 10 | 127 | 3.6 | 0.10 | ND | ND | 0.10 | ND | 0.8 |
| | | | | 92–199 | 2.6–4.8 | 0.05–0.17 | | | 0.05–0.17 | | 0.5–1.4 |
| | 1972 | East | 30 | 161 | 3.7 | 0.12 | 0.04 | 0.03 | 0.19 | 0.01 | 1.0 |
| | | | | 54–755 | 0.5–9.0 | 0.07–0.44 | <0.01–0.33 | <0.01–0.17 | 0.08–0.84 | <0.01–0.04 | 0.5–5.4 |

NOTE: Fish eviscerated, heads and tails removed; alewife, shiner and smelt analyzed whole.
[1] See footnote 1, Table 3.

in yellow perch or gizzard shad (*Dorosoma cepedianum*) (Tables 3, 6, 7).

In the western basin, good examples were not available to show trends, and decline of ΣDDT residues were not so obvious. ΣDDT generally declined in channel catfish, freshwater drum, yellow perch, and rainbow smelt, but not in white bass (Table 6). To observe a decline in ΣDDT for walleye, similar weight classes must be compared (Table 3).

*Dieldrin*—Only white bass and walleye caught in 1975 contained mean residues of dieldrin at or above 0.1 ppm. Three white bass from the western basin had dieldrin levels of 0.12–0.19 ppm, and two from the central basin had 0.17 ppm dieldrin. Two walleye in a catch of 14 fish from west of Pelee Island had the highest resdues, 0.27 ppm and 0.45 ppm. These two fish were the largest of the catch (2.0 kg and 2.3 kg) and contained 20–22 percent fatty tissue (Table 6).

TABLE 7. *Six species of fish caught in all three basins of Lake Erie in either the same year or in a two-year period (1971, 1975–76)*

| Fish Species (Year) | Weight class, kg | Basin[1] | Average Weight, g | Mean Fat, % | Mean Content in Tissue, ppm | | | Number of Fish[3] |
|---|---|---|---|---|---|---|---|---|
| | | | | | ΣDDT | Dieldrin[2] | PCBs | |
| White bass | 0–0.25 | W | 191 | 4.9 | 0.07 | ND | 1.73 | 8 |
| (1971) | | C | 219 | 6.5 | 0.13 | ND | 1.62 | 11 |
| | | E | 127 | 3.6 | 0.10 | ND | 0.80 | 10 |
| Freshwater drum | 0–0.25 | W | 106 | 5.0 | 0.04 | ND | 1.40 | 5(9) |
| (1971) | | C | 176 | 8.5 | 0.11 | ND | 5.50 | 2 |
| | | E | 183 | 6.4 | 0.02 | ND | 1.14 | 7 |
| (1975) | 0.25–0.50 | W | 371 | 4.7 | 0.09 | 0.041 | 0.09 | 7 |
| | | C | 439 | 2.8 | 0.11 | 0.020 | 0.40 | 3 |
| | | E | 372 | 6.8 | 0.11 | 0.050 | 1.20 | 3 |
| | 0.50–0.75 | W | 592 | 4.3 | 0.07 | 0.033 | 0.60 | 3 |
| | | C | 628 | 5.5 | 0.23 | 0.034 | 0.40 | 5 |
| | | E | 574 | 4.4 | 0.16 | 0.045 | 0.95 | 2 |
| Yellow perch | 0–0.25 | W | 116 | 2.0 | 0.02 | ND | 0.96 | 10 |
| (1971) | | C | 102 | 1.7 | 0.03 | ND | 0.34 | 10 |
| | | E | 122 | 2.7 | 0.08 | ND | 0.64 | 9 |
| (1975) | 0–0.25 | W | 40 | 1.7 | 0.07 | 0.030 | 0.60 | 10(59) |
| | | C | 95 | 1.8 | 0.05 | 0.025 | 0.18 | 11(26) |
| | | E | 85 | 2.6 | 0.05 | 0.007 | 0.10 | 21(26) |
| Emerald shiners | 0–0.25 | W | 4.2 | 6.7 | 0.12 | 0.053 | 0.63 | 3(60) |
| (1975) | | C | 6.4 | 7.7 | 0.09 | 0.043 | 0.30 | 3(60) |
| | | E | 5.6 | 5.6 | 0.12 | 0.021 | 0.41 | 4(12) |
| Rainbow smelt | 0–0.25 | W | 29 | 3.4 | 0.08 | 0.030 | 0.45 | 9(60) |
| (1975) | | C | 16 | 3.5 | 0.06 | 0.029 | 0.10 | 6(70) |
| | | E | 16 | 3.2 | 0.10 | 0.029 | 0.34 | 8(23) |
| Coho salmon | 1.0–2.0 | W | 1.9 | 2.9 | 0.31 | 0.075 | 1.35 | 2 |
| (1975–76) | | C | 1.8 | 0.3 | 0.08 | 0.015 | 0.70 | 4 |
| | | E | 1.6 | 2.7 | 0.09 | 0.012 | 0.52 | 1 |
| | 2.0–3.0 | W | 2.8 | 2.1 | 0.25 | 0.068 | 1.05 | 4 |
| | | C | 2.3 | 0.3 | 0.08 | 0.013 | 0.55 | 6 |
| | | E | 2.6 | 1.9 | 0.11 | 0.011 | 0.28 | 3 |
| | 3.0–4.0 | W | 3.8 | 4.3 | 0.32 | 0.095 | 1.40 | 2 |
| | | C | 3.2 | 0.5 | 0.15 | 0.035 | 0.95 | 6 |
| | | E | 3.1 | 1.4 | 0.04 | 0.004 | 0.11 | 1 |

[1] W=western, C=central, E=eastern.
[2] ND=not detected.
[3] See footnote 1, Table 3.

Three species, rainbow trout (*Salmo gairdneri*) caught in 1974, and alewife and coho salmon caught in 1975, had mean residues of dieldrin below 0.1 ppm. Only a few members of these species had levels above 0.1 ppm.

Although differences in dieldrin residues among basins are not apparent, dieldrin residues did increase in 1968–71 and 1975–76, as exhibited by alewife, smallmouth bass, white bass, freshwater drum, yellow perch, gizzard shad, and walleye (Tables 3, 6, 7).

*PCBs*—In the eastern basin, only smallmouth bass caught in 1971 had mean residues of PCBs above the 5.0 ppm U.S. tolerance limit; channel catfish from the western basin averaged 5.0 ppm in the same year (Table 6). In addition, species of white bass caught in the eastern basin in 1972, coho salmon caught in the central basin in 1970, and walleye caught in the western basin in 1975 had individual members whose PCB residues exceeded 5.0 ppm.

Species other than smallmouth bass and channel catfish which had PCB mean residues exceeding the 2.0 ppm Canadian tolerance limit were: alewife from the eastern basin (1971), white bass from the western basin (1971, 1975), freshwater drum from the central basin (1971), coho salmon from the central basin (1970), and gizzard shad from both western and central basins (1971). Among other catches in which the mean residue was below 2.0 ppm PCBs but individual fish exceeded the 2.0 ppm tolerance limit were white bass from the eastern basin (1972), freshwater drum from the western basin (1971), yellow perch from the western basin (1971), and coho salmon from the western basin (1975).

There was no correlation between highest mean residue of PCBs in a species and the basin in which it was caught. In 1971, three species were caught in all three basins. Alewife had the highest mean residues (3.0 ppm) of the eastern basin species; freshwater drum had the highest mean residues (3.7 ppm) of the central basin species; and yellow perch had the highest mean residues (1.0 ppm) of western basin species (Table 6).

In the western basin, white bass and walleye showed increased residues of PCBs between 1968 and 1975 both for mean residues and residues by weight class (Tables 3, 6). Freshwater drum and gizzard shad contained residues of PCBs that increased between 1968 and 1971 and declined in 1975. PCB residues also declined in yellow perch between 1971 and 1975 (Tables 3, 6, 7).

In the central basin, PCBs in coho salmon peaked in

1970 and then declined until 1975. This was true for similar weight classes. PCB residues declined in tissues of white bass, freshwater drum, and gizzard shad in the central basin. No species showed increasing PCB residues, but yellow perch and rainbow smelt, which had low residues in 1968, showed little change in tissue residues by 1975.

In the eastern basin, mean residues of PCBs in smallmouth bass and yellow perch reached a maximum level in 1971 and then declined (Table 6). However, a comparison of fish by weight classes showed that residues of PCBs peaked in 1972 and have shown little change since (Table 3). White bass, freshwater drum, and rainbow smelt had their highest residues in 1971–72 and declined by 1975.

*Chlordane and heptachlor epoxide*—Residues of *cis*- and *trans*-chlordane were first determined in 1972. In that year, *cis*-chlordane was positively identified in only two species, white bass and yellow perch from Long Point Bay, Lake Erie (Table 5). The presence of *trans*-chlordane in the two species was suspected but not confirmed. Chlordane residues in other fish caught between 1972 and 1974 were not confirmed because of the interference of other compounds on the chromatogram.

In 1975–76, both *cis*- and *trans*-isomers of chlordane were detected in white bass, yellow perch, coho salmon, emerald shiner, and rainbow smelt; highest residues were found in rainbow smelt in 1976. Chlordane was also suspected in other species. However, levels were either too low to be confirmed or interfering substances made separation and identification difficult. In 1976, several species were analyzed for oxchlordane but it was not detected.

Heptachlor epoxide was first positively identified in rainbow trout caught in Silver Creek draining into the central basin (Table 5). In 1975 and 1976, residues of heptachlor epoxide were also identified in white bass, yellow perch, coho salmon, emerald shiner, and rainbow smelt. As with chlordane, the highest residues of heptachlor epoxide were found in rainbow smelt.

*Other organochlorine compounds*—Endosulfan was identified in rainbow trout caught in Silver Creek in 1974 (Table 5). Neither endrin nor methoxychlor was identified in any fish caught in Lake Erie. Mirex analysis was added in 1975–76, but no measurable residues were detected.

## *Discussion*

### SEDIMENT AND FISH RESIDUES

Sediments in Lake Erie were five to ten times more highly contaminated with ΣDDT, dieldrin, and PCBs than were sediments from Lake Saint Clair, mostly because sediment is transitory through Lake Saint Clair but accumulates in the basins of Lake Erie (*5*). Fish tissue residues of ΣDDT and dieldrin did not necessarily show this trend, but PCBs were higher in fish from Lake Erie. For example, rock bass and smallmouth bass caught in Lake Erie in 1971 had higher residues of ΣDDT than did those caught in Lake Saint Clair. The reverse was true of channel catfish caught the same year. Dieldrin residues were generally at the trace level in fish from both bodies of water. Residues of PCBs were higher in rock bass, channel catfish, freshwater drum, yellow perch, and walleye caught in Lake Erie than those caught in Lake Saint Clair during the same year. Smallmouth bass were an exception; residues in fish caught in Lake Saint Clair were higher. Frank et al. reported that the parent compound *p,p′*-DDT was low or absent from sediments in Lake Erie (*5*). In the present study, *p,p′*-DDT was not found in many fish caught in Lake Erie.

Sediments collected from the western basin of Lake Erie contained ΣDDT and PCB residues two to three times higher than did sediments in either the central or eastern basins (*5*). Differences in residues among the same species caught during the same year in all three basins were not apparent.

### FISH RESIDUES

Residues of ΣDDT were considerably higher in 1971 than those reported by Reinke et al. in Lake Saint Clair in 1970 (*13*). ΣDDT and dieldrin residues in 13 species of fish caught in 1965–68 in Lake Erie (*11*) were two to nine times higher than those in the same species caught in 1968 in the present study. Samples of gizzard shad in the two studies were similar (0.50 ppm and 0.32 ppm, respectively), but yellow perch samples were different (0.9 ppm and 0.1 ppm, respectively).

Reinke et al. (*13*) reported on ΣDDT and dieldrin residues in six species of fish from Canadian waters of Lake Erie in 1970 which were 1.5–10 times higher than those in similar species reported herein. ΣDDT residues in alewife were similar for the two studies (0.34 ppm and 0.24 ppm, respectively), but residues in freshwater drum and yellow perch were an order of magnitude different.

The site of catch can have a significant bearing on the contaminant residue level (*4*). In fish of the same species, ΣDDT and dieldrin residues were 10–15 times higher in fish caught in streams than in those caught in the lakes. Bluegill (*Lepomis macrochirus*), brown bullhead (*Ictalurus nebulosus*), pumpkinseed (*Lepomis gibbosus*), and rock bass all exhibited ΣDDT and dieldrin residues an order of magnitude higher in fish from creeks draining the tobacco belt of Ontario than in fish caught in Long Point Bay, Lake Erie (*4*).

Residues of ΣDDT, dieldrin, and PCBs reported by Carr et al. (*2*) in fish caught in 1970–71 correspond more closely with the residue levels reported in the present study, especially in the six species common to both surveys.

Residues of ΣDDT in coho salmon caught in 1970 during the present study correspond with those reported by Reinert and Bergman (*12*) for the same species caught in 1969. Coho salmon (1970) weighing 2.0 kg contained 2.2 ppm ΣDDT; coho salmon (1969) weighing 2.2 kg had 2.8 ppm ΣDDT.

Suns and Rees documented residues in spottail shiners from both the western and the eastern basins of Lake Erie (*15*). ΣDDT and dieldrin levels in spottail shiners from the western basin reported in the present study are similar to those of Suns and Rees (*15*), but PCB residues are lower by an order of magnitude. Emerald shiners caught close to the same location, however, contained similar PCB levels (0.6 ppm). Suns and Rees reported that spottail shiner are good indicators of specific site effluents of PCBs (*15*).

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# *Organochlorine Residues in Aquatic Environments in Iran, 1974*

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ABSTRACT

*Organochlorine pesticide residues in various organisms from different aquatic ecosystems in Iran were investigated in spring 1974. DDT levels were high in fish taken from two rivers in southern Iran, whereas low levels were detected in samples obtained from a freshwater lake in the same area. Fish from two of the reservoirs supplying Tehran with potable water contained moderate levels of DDT. The low residue level in pike collected in the Bandar-Pahlavi Mordab in northwest Iran indicates that only a small amount of organochlorine pesticides used in this area enters the pelagic food chain.*

*Sturgeon collected at different places in the Caspian Sea showed similar accumulations of DDT in the muscles and in the eggs. Polychlorinated biphenyls (PCBs) were detected only in samples of sediment from the drainage systems in Tehran.*

## *Introduction*

Although reports on the widespread distribution of organochlorine pesticide residues in the global ecosystem are increasing *(4, 5, 8, 10, 11, 17)*, very little is known of their occurrence, distribution, effects, and ecological significance in many developing countries. Because large quantities of pesticides are used in such countries for agriculture and in vector control programs, information is needed to evaluate the full effects and benefits of pesticidal applications.

Iran imported about 2,720 tons/year of organochlorine pesticides during 1966–75; DDT was the main import (Table 1). Consumption increased considerably during that period, and the amount of DDT compounds imported during 1974–75 was about 10 times that imported in 1966–67. Far-reaching ecological implications may be foreseen regarding the stability of the pesticides and their readiness to accumulate in food chains, especially in areas subjected to regular, intense applications.

During 1970–72, Higgins *(3)* analyzed various samples from the Caspian Sea for DDT and heavy metals. Hashemy-Tonkabony and Asadi Langaroodi *(2)* studied organochlorine pesticide residues in 14 species of fish from the Caspian Sea. The levels found by Higgins were not regarded as hazardous, but a closer study of the occurrence, distribution, and possible effects of these pesticides in selected biota was recommended.

The purpose of the present study was to monitor certain areas in Iran to evaluate the level of contamination and its significance.

### *Substances Investigated*

Samples were analyzed for benzene hexachloride (BHC), lindane, aldrin, dieldrin, DDT, and polychlorinated biphenyls (PCBs). All except PCBs are widely used in Iran as insecticides.

The form of DDT most used in pesticide formulations contains approximately 70 percent *p,p'*-DDT and 20 percent *o,p'*-DDT; the remaining 10 percent contains at least seven different substances *(1)*. Therefore, it is assumed that DDT enters the environment mainly as *p,p'*-DDT or *o,p'*-DDT. In a study of the distribution of DDT and its metabolites in the environment, the pattern of degradation may be used to evaluate DDT input to the ecosystem.

PCBs include at least 50 different compounds, homologs, or isomers. They are not spread as pesticides, but are

TABLE 1. *Amount of chlorinated hydrocarbons imported to Iran, 1966–75*[1]

| Year | Total Chlorinated Hydrocarbons, Tons | DDT Compounds, Tons |
|---|---|---|
| 1966–67 | 1005 | 514 |
| 1967–68 | 850 | 585 |
| 1968–69 | 2137 | 1214 |
| 1969–70 | 1799 | 1168 |
| 1970–71 | 1965 | 1142 |
| 1971–72 | 3347 | 2967 |
| 1972–73 | 1247 | 517 |
| 1973–74 | 5841 | 3620 |
| 1974–75 | 6291 | 5786 |

[1] SOURCE: Department of the Environment and the Plant Protection Department, Tehran, Iran.

[1] Present address: Institute of Limnology, University of Lund, Sweden.

[2] Department of the Environment, P.O. Box 1430, Tehran, Iran.

used in industry as heat-transfer media, lubricants, waxes, and synthetic resins to improve chemical resistance, adhesiveness, and flexibility *(9)*. The sources of PCBs and their modes of transport into the environment are poorly understood.

## *Materials and Methods*

### SAMPLING

Samples of various organisms collected in spring 1974 were frozen and brought to the laboratory in Tehran. Sturgeon and their eggs were sampled at three places along the Iranian Caspian Sea coast. Birds and fish from Parishan Lake and the Shapour and Kupor Rivers, situated in the Shiraz area in southern Iran, were sampled. Fish from water reservoirs near Tehran were also analyzed, as well as pike from the Bandar Pahlavi region, 300 km northwest of Tehran (Figure 1).

From sturgeon, a section of the dorsal musculature just behind the gills was excised. The skin was removed, and the sample was wrapped in aluminum foil and frozen until processed. The sturgeon eggs were removed and frozen in a similar manner. From other fish, a section of the lateral body muscle from the left side of the fish, anterior to the anal openings, was taken for analysis. From the birds, the breast muscle was sampled.

1. Bandar Pahlavi (sturgeon)
2. Babulsar (sturgeon)
3. Miankaleh and Tazze Abad (sturgeon)
4. Bandar Pahlavi Mordab (pike)
5. Parishan Lake, Shapour and Kupor Rivers (fish and birds)

FIGURE 1. *Location of sampling areas in Iran*

### ANALYTICAL METHODS

Organochlorine residues were extracted, cleaned, and separated and quantitated by gas chromatography by the method of Södergren *(12)*.

Samples (1–3 g) were homogenized in a 1:1 solution of acetone–hexane. After acetone was removed, the hexane extract was evaporated to 1 ml and divided into thirds for subsequent cleanup and fat determination.

Two cleanup processes, one acidic and one involving basic hydrolysis, were performed simultaneously for each sample. The compounds were chemically derivatized, and the conversion products were used to confirm the identity of the original compounds. *p,p'*-DDT and *p,p'*-TDE were treated with potassium hydroxide and quantitatively converted to *p,p'*-DDE and *p,p'*-DDMU [1-chloro-2,2-bis(*p*-chlorophenylethylene)], respectively. In the acidic treatment, dieldrin is degraded but is recovered in the potassium hydroxide–treated extract. On the other hand, lindane and benzene hexachloride (BHC) are lost in the KOH procedure, but are recovered in the acidic treatment. Neither treatment affects the PCBs.

Two hundred μl of the extract was taken for gravimetric determination of extractable lipids in the sample.

The hexane extracts were analyzed by gas-liquid chromatography on a Model 2700 Varian Aerograph equipped with a Hoechst Oxysorb filtering unit. A modified electron-capture detector was used *(13)*. The system, all glass from the injector to the detector, diminishes the risk of pyrolysis. Sensitivity was also increased over that of conventional Kovar cells. Instrument parameters and operating conditions follow.

| | |
|---|---|
| Column: | 205 cm long × 1.5 mm ID glass, packed with a 3:1 mixture of 4 percent SF-96 and 8 percent QF-1 on 100–120-mesh Chromosorb W AW/DMCS |
| Resolution: | approximately 1700 theoretical plates for *p,p'*-DDT |
| Temperatures: | column 185°C<br>injector 225°C<br>detector 220°C |
| Carrier gas: | nitrogen flowing at 25 ml/minute |

The quantity of organochlorines in the samples was estimated by comparing peak heights of aliquots of purified extracts with peak heights of a known quantity of a standard solution. The results were not corrected for recovery. For the PCBs, a commercially available mixture, Clophen A50, was used as a reference.

TABLE 2. *Organochlorine residues in organisms from Parishan Lake, Kupor and Shahpour Rivers—1974*

| Location | Species | Fat, % | Fresh Weight, ng/g | | | | Fat Weight, mg/kg | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | DDE | TDE | DDT | ΣDDT | DDE | TDE | DDT | ΣDDT |
| Parishan Lake | *Barbus* sp. | 0.4 | 7 | ND | ND | 7 | 1.7 | ND | ND | 1.7 |
| | | 0.4 | 7 | ND | ND | 7 | 1.8 | ND | ND | 1.8 |
| | | 0.3 | 3 | ND | ND | 3 | 1.2 | ND | ND | 1.2 |
| | Coot, *Fulica atra* | 2.4 | 37 | ND | ND | 37 | 1.6 | ND | ND | 1.6 |
| Kupor River | *Barbus* sp. | 0.8 | 1425 | ND | 180 | 1605 | 174.0 | ND | 22.0 | 196.0 |
| | | 0.4 | 1161 | 261 | 241 | 1662 | 72.9 | 16.4 | 15.1 | 104.4 |
| | | 0.1 | 251 | 30 | 39 | 320 | 482.3 | 57.6 | 74.9 | 614.8 |
| Shahpour River | *Varichorhinus* sp. | 2.5 | 3030 | 118 | 910 | 4058 | 121.2 | 4.7 | 36.4 | 162.3 |
| | *Barbus* sp. | 0.5 | 250 | 18 | 30 | 298 | 50.8 | 3.7 | 6.1 | 60.6 |

NOTE: ND=not detected.

## *Results*

Only small amounts of *p,p'*-DDE were detected in fish from Parishan Lake and in a coot which was found dead (Table 2). Fish obtained from the Shahpour and Kupor Rivers contained appreciable amounts of DDT and its metabolites DDE and TDE (Table 2). The Shahpour and Kupor Rivers flow through malaria-infected areas, and DDT is used for indoor spraying.

In fish and fish eggs from two reservoirs supplying Tehran with potable water, various amounts of DDT were detected (Tables 3, 4). The levels in cyprinide fish *(Varichorhinus nikolskii)* from the Latian reservoir far exceeded those found in fish from the Karadj reservoir. The main metabolite accumulated was *p,p'*-DDE.

In samples from the Latian reservoir, the levels of DDT compounds in rainbow trout *(Salmo gairdneri)* were similar to those found in *V. nikolskii*. The *Varichorhinus* species has a shorter food chain than the *Salmo* species, resulting in a deviation from the usual pattern of biomagnification of persistent compounds.

Low levels of DDT were found in pike *(Esox lucius)* collected from the Bandar Pahlavi Mordab (Table 5). Again, the principal metabolite found was *p,p'*-DDE. The presence of only small proportions of *p,p'*-DDT suggests that the accumulation occurred over considerable time, and that the input is not recent.

In May 1974, more than 100 samples of sturgeon and their eggs were collected from two species *(Accipencer*

TABLE 3. *Organochlorine residues in fish and fish eggs from the Latian Dam, 1974*

| Species | Fat, % | Fresh Weight, ng/g | | | | Fat Weight, mg/kg | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | DDE | TDE | DDT | ΣDDT | DDE | TDE | DDT | ΣDDT |
| *Salmo gairdneri* | 0.7 | 13 | 2 | 13 | 28 | 1.6 | 0.3 | 1.6 | 3.2 |
| | 0.2 | 650 | ND | ND | 650 | 88 | ND | ND | 88 |
| | 1.4 | 97 | ND | ND | 97 | 41 | ND | ND | 41 |
| | 1.0 | 340 | ND | ND | 340 | 24 | ND | ND | 24 |
| | 2.4 | 75 | ND | ND | 75 | 7.9 | ND | ND | 7.9 |
| *Varichorhinus nikolskii* | 1.9 | 178 | 81 | 8 | 267 | 9.5 | 4.3 | 0.4 | 14.2 |
| | 2.2 | 245 | 17 | ND | 262 | 11 | 0.8 | ND | 11.8 |
| | 0.7 | 92 | 10 | ND | 102 | 10.6 | 1.2 | ND | 11.8 |
| | 1.7 | 129 | ND | 10 | 139 | 7.6 | 0 | 0.6 | 8.2 |
| | 1.4 | 77 | ND | ND | 77 | 5.7 | ND | ND | 5.7 |
| *Alburnoides bipantatur* | 0.8 | 185 | 19 | ND | 204 | 24.2 | 2.5 | ND | 26.7 |
| | 0.5 | 410 | 26 | ND | 436 | 262.7 | 16.4 | ND | 279.1 |
| *Coregonus* sp. | 0.8 | 13 | 2 | 13 | 28 | 1.6 | 0.3 | 1.6 | 3.5 |
| Eggs from *S. gairdneri*[1] | 1.6 | 235 | 21 | ND | 256 | 14.3 | 1.3 | ND | 15.6 |

NOTE: ND=not detected.
[1]Pooled sample from six individuals.

TABLE 4. *Organochlorine residues in cyprinide,* Varichorhinus nikolskii, *from Karadj Reservoir, 1974*

| Fat, % | Fresh Weight, ng/g | | | | Fat Weight, mg/kg | | | |
|---|---|---|---|---|---|---|---|---|
| | DDE | TDE | DDT | ΣDDT | DDE | TDE | DDT | ΣDDT |
| 0.3 | 11 | 3 | ND | 14 | 4.7 | 1.1 | ND | 5.8 |
| 0.6 | 23 | ND | ND | 23 | 3.8 | ND | ND | 3.8 |
| 0.6 | 11 | ND | ND | 11 | 1.7 | ND | ND | 1.7 |
| 0.2 | 8 | ND | ND | 8 | 3.7 | ND | ND | 3.7 |
| 0.9 | 22 | ND | ND | 22 | 2.4 | ND | ND | 2.4 |

NOTE: ND=not detected.

TABLE 5. *Organochlorine residues in pike,* Esox lucius, *from Bandar Pahlavi Mordab, 1974*

| Age, Years | Fat, % | Fresh Weight, ng/g | | | | Fat Weight, mg/kg | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | DDE | TDE | DDT | ΣDDT | DDE | TDE | DDT | ΣDDT |
| 3+ | 0.7 | 3 | ND | ND | 3 | 0.4 | ND | ND | 0.4 |
| 3+ | 1.1 | 6 | ND | ND | 6 | 0.6 | ND | ND | 0.6 |
| 3+ | 0.6 | 5 | ND | ND | 5 | 1.2 | ND | ND | 1.2 |
| 3+ | 0.7 | 17 | ND | ND | 17 | 2.3 | ND | ND | 2.3 |
| 3+ | 0.6 | 3 | ND | ND | 3 | 0.6 | ND | ND | 0.6 |
| 3+ | 0.5 | 9 | ND | ND | 9 | 2.0 | ND | ND | 2.0 |
| 3+ | 0.7 | 5 | ND | ND | 5 | 0.7 | ND | ND | 0.7 |
| 3+ | 0.5 | 8 | ND | ND | 8 | 1.3 | ND | ND | 1.3 |
| 3+ | 0.5 | 2 | ND | ND | 2 | 0.4 | ND | ND | 0.4 |
| 3+ | 0.4 | 4 | ND | ND | 4 | 0.9 | ND | ND | 0.9 |

NOTE: ND=not detected.

TABLE 6. *Organochlorine residues in sturgeon,* Accipenser stellatus, *from Miankaleh and Tazze Abad at the Caspian Sea, 1974*

| Sample | Weight, kg | Fat, % | Fresh Weight, ng/g | | | | | Fat Weight, mg/kg | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Lindane | DDE | TDE | DDT | ΣDDT | Lindane | DDE | TDE | DDT | ΣDDT |
| Muscle | 9.5 | 2.6 | 4 | 14 | 7 | | 21 | 0.2 | 0.5 | 0.3 | | 0.8 |
| Eggs | | 17.5 | 13 | 67 | 16 | 8 | 91 | 0.1 | 0.4 | 0.1 | 0.1 | 0.6 |
| Muscle | 9.0 | 3.0 | 2 | 16 | 4 | 4 | 24 | 0.1 | 0.5 | 0.1 | 0.1 | 0.7 |
| Eggs | | 17.3 | ND | 84 | 31 | 18 | 133 | ND | 0.5 | 0.2 | 0.1 | 0.8 |
| Muscle | 7.0 | 6.6 | ND | 276 | 46 | 149 | 471 | ND | 4.2 | 0.7 | 2.3 | 7.2 |
| Eggs | | 16.1 | 23 | 494 | 484 | 224 | 1202 | 0.2 | 3.1 | 3.0 | 1.4 | 7.5 |
| Muscle | 8.0 | 4.8 | 7 | 96 | 19 | 44 | 159 | 0.2 | 2.0 | 0.4 | 0.9 | 3.3 |
| Eggs | | 19.4 | 26 | 471 | 54 | 141 | 666 | 0.2 | 2.4 | 0.3 | 0.7 | 3.4 |
| Muscle | 8.5 | 2.0 | ND | 25 | 7 | 10 | 42 | ND | 1.2 | 0.4 | 0.5 | 2.1 |
| Eggs | | 16.6 | 15 | 193 | 37 | 55 | 285 | 0.2 | 1.2 | 0.2 | 0.3 | 1.7 |
| Muscle | 10.5 | 3.1 | 4 | 208 | 97 | 126 | 431 | 0.2 | 6.7 | 3.1 | 4.1 | 13.9 |
| Eggs | | 16.6 | 17 | 996 | 125 | 662 | 1783 | 0.1 | 6.0 | 0.8 | 4.0 | 10.8 |
| Muscle | 9.5 | 4.1 | 5 | 27 | 14 | 10 | 51 | 0.1 | 0.7 | 0.3 | 0.3 | 1.3 |
| Eggs | | 16.9 | 17 | 79 | 38 | 27 | 144 | 0.1 | 0.5 | 0.2 | 0.2 | 0.9 |
| Muscle | 8.0 | 5.0 | 6 | 26 | 19 | 11 | 56 | 0.1 | 0.5 | 0.4 | 0.2 | 1.1 |
| Eggs | | 19.6 | 23 | 79 | 44 | 34 | 157 | 0.2 | 0.4 | 0.2 | 0.2 | 0.8 |
| Muscle | 9.0 | 6.0 | 7 | 92 | 19 | 46 | 157 | 0.2 | 1.5 | 0.3 | 0.8 | 2.6 |
| Eggs | | 14.3 | 13 | 204 | 38 | 77 | 319 | 0.1 | 1.4 | 0.3 | 0.5 | 2.2 |
| Muscle | 8.5 | 2.5 | ND | 55 | 12 | 20 | 87 | ND | 2.2 | 0.5 | 0.8 | 3.5 |
| Eggs | | 14.0 | 16 | 300 | 48 | 114 | 462 | 0.2 | 2.1 | 0.3 | 0.8 | 3.2 |

NOTE: ND=not detected.

*guldenstadti* and *A. stellatus)* from three different places along the Iranian coast of the Caspian Sea (Figure 1). From these, 20 samples of *A. stellatus* of similar size and weight were analyzed (Table 6). Fat content in the muscle was 2.0–6.6 percent; corresponding range for the eggs was 12.0–19.6 percent. Calculated on the extractable lipid fraction, the average levels of DDT in muscle and egg were 3.7 ppm and 3.2 ppm, respectively. BHC and lindane were detected, but no PCBs were found.

No significant differences in the distribution of DDT and its metabolites in egg and muscle were revealed (Table 7). The range of DDT found in muscles of four species of sturgeon sampled at Babolsar in March 1974 was 1.0–13.1 ppm (Table 8). For *A. stellatus,* the mean level of DDT was 4.7 ppm.

The only samples in which PCBs were detected came from Tehran. Sediment from the drainage system along the streets contained appreciable amounts of DDT and PCBs (Table 9).

TABLE 7. *Distribution of DDT and its metabolites in muscle and eggs of sturgeon,* Accipenser stellatus*—1974*

| Sample | % DDE | % TDE | % DDT |
|---|---|---|---|
| Muscle | 82 | 38 | |
| | 72 | 14 | 14 |
| | 58 | 10 | 32 |
| | 61 | 12 | 27 |
| | 57 | 19 | 24 |
| | 48 | 22 | 30 |
| | 54 | 23 | 23 |
| | 45 | 36 | 19 |
| | 58 | 12 | 30 |
| | 63 | 14 | 23 |
| Mean | 58 | 20 | 22 |
| Eggs | 80 | 20 | |
| | 82 | 25 | 13 |
| | 41 | 40 | 19 |
| | 71 | 9 | 20 |
| | 71 | 12 | 17 |
| | 56 | 7 | 37 |
| | 56 | 22 | 22 |
| | 50 | 25 | 25 |
| | 64 | 14 | 22 |
| | 66 | 9 | 25 |
| Mean | 64 | 16 | 20 |

TABLE 8. *Organochlorine residues in sturgeon from Babolsar at the Caspian Sea, 1974*

| Species | Fat, % | Fresh Weight, ng/g | | | | | Fat Weight, mg/kg | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Lindane | DDE | TDE | DDT | ΣDDT | Lindane | DDE | TDE | DDT | ΣDDT |
| *Accipenser guldenstadti* | 2.6 | 1 | 95 | 11 | 56 | 162 | 0.1 | 3.5 | 0.4 | 2.1 | 6.0 |
| | 1.7 | ND | 41 | ND | 15 | 56 | ND | 2.5 | ND | 0.9 | 3.4 |
| | 1.5 | 2 | 18 | ND | 7 | 25 | 0.1 | 1.3 | ND | 0.9 | 1.8 |
| | 0.5 | 1 | 51 | 1 | 19 | 71 | 0.1 | 1.0 | ND | 0.4 | 1.4 |
| | 2.4 | 1 | 37 | 5 | 21 | 63 | 0.1 | 1.5 | 0.2 | 0.9 | 2.6 |
| | 2.0 | 1 | 23 | ND | 1 | 24 | 0.1 | 1.1 | ND | 0.1 | 1.1 |
| | 3.7 | 1 | 24 | 3 | 22 | 49 | 0.1 | 0.6 | 0.1 | 0.6 | 1.2 |
| | 2.7 | 16 | 220 | ND | 142 | 362 | 0.5 | 8.0 | ND | 5.1 | 13.1 |
| | 4.8 | ND | 106 | 10 | 85 | 201 | ND | 2.2 | 0.2 | 1.7 | 4.1 |
| *A. stellatus* | 1.0 | ND | 12 | ND | 7 | 19 | ND | 2.2 | ND | 0.7 | 1.9 |
| | 1.2 | ND | 84 | 3.6 | 51 | 139 | ND | 6.7 | 0.3 | 4.1 | 11.1 |
| | 4.6 | ND | 239 | ND | 119 | 368 | ND | 4.9 | ND | 2.5 | 7.7 |
| | 3.7 | ND | 310 | 40 | 240 | 59 | ND | 3.9 | 0.5 | 3.0 | 7.4 |
| | 5.7 | 9 | 141 | 22 | 155 | 318 | 1.1 | 2.5 | 0.4 | 2.7 | 5.6 |
| | 5.0 | ND | 64 | 32 | 71 | 167 | ND | 1.2 | 0.7 | 1.3 | 3.2 |
| | 2.9 | ND | 23 | ND | 18 | 41 | ND | 0.8 | ND | 0.6 | 1.4 |
| | 10.4 | ND | 242 | ND | 84 | 326 | ND | 2.3 | ND | 0.8 | 3.1 |
| | 0.5 | ND | 15 | ND | 3 | 18 | ND | 2.7 | ND | 0.6 | 3.3 |
| | 1.4 | ND | 56 | ND | 31 | 87 | ND | 3.9 | ND | 2.1 | 6.0 |
| *A. nudiventris* | 2.9 | 1 | 27 | 2 | 8 | 37 | 0.1 | 0.9 | 0.1 | 0.3 | 1.3 |
| | 12.3 | | 76 | 12 | 45 | 133 | | 0.6 | 0.1 | 0.4 | 1.0 |
| | 2.7 | 5 | 28 | 5 | 18 | 56 | 0.2 | 1.1 | 0.2 | 0.7 | 2.0 |
| *Huso huso* | 0.6 | | 26 | ND | 9 | 35 | | 4.0 | ND | 1.3 | 5.4 |

NOTE: ND=not detected.

TABLE 9. *Organochlorine residues in sediment from street drainage systems in Tehran, 1974*

| Street | Wet Weight, ng/g | |
|---|---|---|
| | ΣDDT | PCB |
| Karim Kahn Zand | 85 | 138 |
| Fisherabad | 112 | 155 |
| ShahAbbas | 35 | ND |

NOTE: ND=not detected.

## *Discussion*

Fish are exposed to pesticide residues not only in the water but in food and sediments. Some fish continue to accumulate residues over a period of years. Therefore, the levels in the fish may reflect their integrated history of exposure and can be used to assess the degree of pesticide contamination in a freshwater ecosystem.

Food can be a significant source of residues if the prey species has had a greater exposure in its physical environment than has its predator. However, biomagnification of persistent residues does not depend simply on position in the food chain but is basically determined by the rate at which the residue is taken up and eliminated. Although of limited statistical significance, the results from the Latian reservoir show that despite a lower trophic position *the Varichorhinus* species accumulated about the same amount of DDT as did the *Salmo* species.

DDT and its metabolites were the principal organochlorine residues detected. Aldrin or dieldrin was not found, and PCBs occurred in significant quantities only in samples collected in Tehran.

Very high levels of DDT were found in fish from the Kupor and Shahpour Rivers in southern Iran. The proportions of the DDT not metabolized, 12 percent in Kupor River samples and 16 percent in Shahpour River samples, indicate that the input of DDT to the rivers is of recent origin and/or is still occurring. DDT probably originates from the mosquito-spraying operations in these areas.

Only the indoors are sprayed. The results of this study, however, suggest a more direct contamination. Interviews with villagers indicate that, at several places, the spraying equipment was cleaned in the rivers after spraying was completed.

Very low levels of residues were found in organisms from the Parishan Lake. The levels are comparable to those found in areas subjected only to airborne contamination *(14)*. However, due to the limited number of samples processed from Parishan Lake and the Kupor and Shahpour Rivers, the results are only tentative. The distribution within these areas requires further studies. However, the high levels found in the Kupor and Shahpour Rivers may adversely affect reproduction of certain fish species.

Comparison of DDT levels in cyprinide fish from the Latian and Karadj reservoirs shows that the Latian reservoir is more exposed to pesticide contamination than is the Karadj reservoir.

Pike collected from Bandar Pahlavi Mordab show remarkably low levels of DDT in the muscles. The pike is a predatory fish and usually accumulates persistent substances readily. DDT has been used in the area for agriculture and in vector control programs. However, due to runoff, the amount of clay and soil particles in the water is extremely high. So, most DDT probably

enters the lake attached to these particles, settles to the bottom, and is not directly incorporated in the pelagic food chain.

The amounts of DDT found in the muscle and eggs of sturgeon from the Caspian Sea were similar to those reported by Higgins *(3)* but higher than those found by Hashemy-Tonkabony and Asadi Langaroodi *(2)*.

The magnitude and pattern of accumulation of DDT in sturgeon muscle and eggs is closely related to the fat content. When calculated on a fat-weight basis, the amount accumulated in muscle and eggs of individual fish is not significantly different. Thus, the accumulation of DDT and its metabolites in muscle and eggs of the sturgeon seems to be of a similar magnitude.

It is well known that even if the DDT accumulated by fish does not harm the individual, it might be disastrous for the population. This is because DDT may, even at low levels, interfere with the reproduction of certain species *(6)*. Present levels of DDT found in the sturgeon eggs may be a threat to the sturgeon population. However, different species respond differently to the influence of accumulated compounds. Lack of experimental information on the sensitivity of sturgeon to organochlorine pesticide residues make it impossible to evaluate the present threat.

The occurrence of PCBs in various components of the global ecosystem is well documented *(4, 5, 7, 10, 11)*. In Europe, and especially in industrialized areas, PCBs are frequently found in the biota and in airborne fallout *(15, 16)*.

In Iran, however, there is not yet any sign of a widespread contamination by PCBs as indicated by the absence of these compounds in the organisms analyzed. PCBs have only been found in samples collected in Tehran, presumably originating from local runoff. Strict regulation of the PCBs and PCB-containing products might prevent their accumulation in food chains and reduce their impact on the environment.

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# *Chlorinated Hydrocarbon Pesticide Residues in Pacific Oysters* (Crassostrea gigas) *from Tasmania, Australia—1973*

Colin Edward Sumner[1]

ABSTRACT

*Pacific oysters* (Crassostrea gigas *Thunberg*) *from 19 sites in Tasmania were surveyed for pesticide residues. All samples were analyzed for dieldrin and DDT, and five samples were analyzed for hexachlorobenzene (HCB) and lindane. Only DDT was found in all samples. Dieldrin levels were high in oysters from the Tamar River, but were highest (0.39 mg/kg wet weight) in samples from Ruffin's Bay. In contrast, other residue levels were low. Distribution of pesticides in Tamar River samples differed: dieldrin could be correlated with industrial uses upstream and DDT could be correlated with low-level widespread agricultural use.*

## *Introduction*

Pacific oysters (*Crassostrea gigas* Thunberg), imported from Japan for cultivation trials, successfully reproduced themselves and colonized estuarine areas in the Tamar River, northern Tasmania (*15, 16, 17*). They represent the only commercial breeding stocks of Pacific oysters in Australia, and an oyster industry has evolved using annual spatfalls. Stick and shell cultch are set in January and later relaid on growing areas around the state. Oyster spat from the river are also sold to growers in South Australia and are being used in cultivation trials in Tongan saltwater lagoons (P. Dinamani, Fisheries Research Division, New Zealand. 1977. Personal communication).

Wild oysters abound on the shores of the Tamar River within easy access of the general public. In contrast, oyster farms are located on intertidal mud/sand flats leased from the state for private use by individuals and companies.

In February 1973, dieldrin and DDT residues in Tamar River oysters were surveyed to assess the risk of spatfall failure resulting from pesticide accumulation by adult oysters (*3, 7, 9*). The results indicated that significant levels of pesticides were present in oyster tissues, and a complete survey of major oyster beds in the Tamar River and other oyster-growing areas was commissioned to investigate more fully the risk of spatfall failure and to establish pesticide levels in oysters available to the general public.

## *Sampling and Analytical Methods*

Oysters were collected from 14 sites in the Tamar River: four oyster farms and ten natural reefs. Samples were also taken from five farms in other areas of the state (Fig. 1). Tamar sampling sites were identical to those chosen for a heavy metal survey (*1*). Samples of 12 oysters were considered representative of the local population (*2*). Ages of cultivated oysters were noted and, when available, year classes were sampled independently.

All samples were routinely screened for dieldrin and ΣDDT residues. Five samples were analyzed also for hexachlorobenzene (HCB) and lindane. DDT here includes ΣDDT resdues and *p,p'*-TDE and *p,p'*-DDE. Analyses were performed at the Public Health Service Analysts Laboratory, Hobart, Tasmania.

Shucked undrained oyster meats were stored at −18°C, in mason jars. Before analysis, they were homogenized in an electric blender. Oyster meats were combined with a desiccant, anhydrous sodium sulfate (1:3, wet weight), and alternately blended and chilled until smooth flowing. Standard procedures were followed for cleaning high-moisture nonfatty foods (*18*). Aliquots were extracted with acetonitrile and were diluted with water before hexane partitioning. The hexane extract was backwashed with distilled water and filtered through a Florisil column.

The column was packed with activated magnesium silicate and topped with 1 cm of anhydrous sodium sulfate. Residues were eluted from the column with 6 percent and 15 percent ethyl ether in petroleum ether. The 6 percent eluate was used directly to determine DDT residues, HCB, and lindane. The 15 percent eluate was concentrated and subjected to additional cleanup through a new Florisil column.

Samples eluted from the Florisil columns were identified and quantitated by using a Varian Model 1400 gas

[1]Present address: Tasmanian Fisheries Development Authority, P.O. Box 619F, Hobart, Tasmania, Australia, 7001.

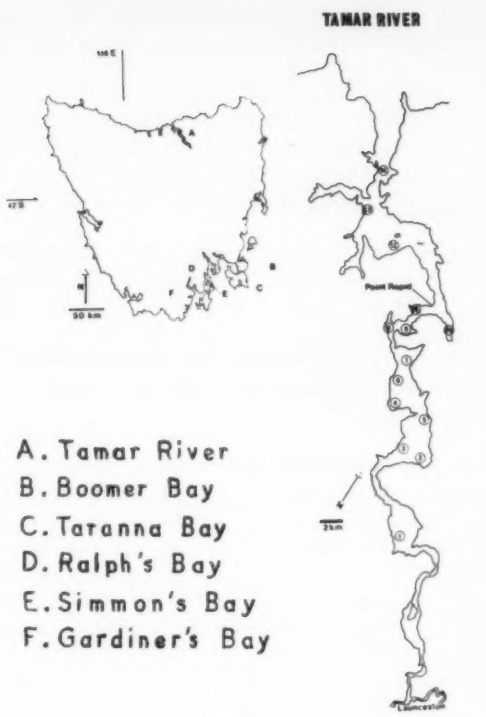


FIGURE 1. *Oyster sampling sites, Tasmania, Australia with map of Tamar River area—1973 (A: Tamar R.; B. Boomer Bay; C. Taranna Bay; D. Ralph's Bay; E. Simmons Bay; F. Gardners Bay)*

chromatograph equipped with an electron-capture detector. Instrument parameters and operating conditions follow.

| | |
|---|---|
| Columns: | Pyrex, 5-ft × ⅛-inch diameter, packed with a mixture of 3 percent DC-200 and 5 percent QF-1 on 80–100-mesh Gas-Chrom Q |
| Temperatures: | detector 200°C<br>injector 210°C<br>oven 185°C |
| Carrier gas: | nitrogen flowing at 40 ml/minute |

Thin-layer chromatography was used to check results obtained by gas chromatography and to check for possible interference from the presence of polychlorinated biphenyls (PCBs). Samples fortified with 1 μg of each compound produced average recoveries of 88 percent ΣDDT, 93 percent HCB and lindane, and 90 percent dieldrin. All data reported are corrected for recovery. The lower limit of quantitation was 10 ppb (10 μg/kg); values less than this but for positively identified peaks were recorded as trace.

## *Results*

Residue levels of dieldrin, ΣDDT, HCB, and lindane in whole oyster meats are presented in Table 1. Dieldrin was detected in all but three samples. Elevated levels in oysters from the Tamar River were reflected in a high of 0.39 μg/g in the Ruffins Bay sample. ΣDDT residues were positively identified from all samples but were of an order of magnitude lower than dieldrin levels, ranging from trace to 0.06 μg/g. Traces of HCB were found only in the Gardners Bay oysters, and traces

TABLE 1. *Pesticide levels in Pacific oysters* (Crassostrea gigas), *Tasmania, Australia*

| | Sampling Station | Sampling Date | Age, Year | No. Bulked | Residues, mg/kg, Whole Oyster | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Dieldrin | ΣDDT | HCB | Lindane |
| *TAMAR RIVER* | | | | | | | | |
| 1 | Rosevears | March 1973 | — | 18 | 0.20 | 0.03 | — | — |
| 2 | Swan Bay | March 1973 | — | 12 | 0.10 | 0.02 | — | — |
| 3 | Gravelly Beach | March 1973 | — | 15 | 0.21 | 0.01 | — | — |
| 4 | Supply River[1] | February 1973 | 2 | 17 | 0.20 | 0.02 | — | — |
| | | March 1973 | 2 | 15 | 0.09 | 0.01 | — | — |
| 5 | Hillwood Jetty | March 1973 | — | 22 | 0.10 | 0.02 | — | — |
| 6 | Devoit | March 1973 | — | 12 | 0.10 | 0.02 | — | — |
| 7 | Craigburn | March 1973 | — | 22 | 0.19 | 0.01 | — | — |
| 8 | Devils Elbow | March 1973 | — | 20 | 0.10 | 0.01 | — | — |
| 9 | Redwood Bay | February 1973 | — | 16 | 0.19 | 0.03 | — | — |
| | | March 1973 | — | 12 | 0.09 | 0.01 | — | — |
| 10 | Ruffins Bay[1] | February 1973 | 2 | 13 | 0.39 | 0.01 | — | — |
| | | March 1973 | 3 | 22 | 0.27 | 0.06 | — | — |
| 11 | East Arm[1] | February 1973 | 1 | 34 | 0.10 | 0.02 | — | — |
| | | | 2 | 15 | 0.09 | 0.02 | — | — |
| | | | 3 | 19 | 0.19 | 0.01 | — | — |
| | | March 1973 | 2 | 19 | 0.08 | 0.01 | — | — |
| | | | 3 | 13 | 0.20 | 0.01 | — | — |
| 12 | Middle Island[1] | February 1973 | 3 | 16 | 0.11 | 0.03 | — | — |
| | Flats | March 1973 | 2 | 21 | 0.09 | 0.02 | — | — |
| | | | 3 | 19 | 0.10 | 0.01 | — | — |
| 13 | West Arm | March 1973 | — | 14 | 0.09 | 0.01 | — | — |
| 14 | Bryants Bay | March 1973 | — | 14 | 0.08 | 0.01 | — | — |
| | *Boomer Bay*[1] | August 1973 | 1.5 | 15 | ND | T | ND | T |
| | *Taranna Bay*[1] | July 1973 | 1.5 | 15 | T | T | ND | T |
| | *Ralphs Bay*[1] | January 1972 | 2 | 24 | ND | T | — | — |
| | *Simmons Bay*[1] | August 1973 | 1.5 | 15 | ND | 0.01 | ND | T |
| | *Gardners Bay*[1] | July 1973 | 1.5 | 15 | T | 0.06 | T | T |

NOTE: —=not analyzed, ND=not detected, T=<0.01 mg/kg.
[1]Oyster farms.

of lindane were identified in samples from three of the leased farms.

The limited sampling of oysters of different ages from growing areas in the Tamar River suggests few differences in pesticide concentrations among the groups; this agrees with Butler's observations (*2*).

Tamar River samples taken at increasing distances downriver from Launceston showed differences in pesticide concentrations in oyster fats (Fig. 2). Dieldrin levels were inversely correlated with distance from Launceston ($r = 0.900$; $P = 0.001$), whereas DDT levels showed a more general spread suggestive of wide-scale low-level use of the pesticide ($r = 0.490$; $0.05 < P < 0.10$).

## *Discussion*

Levels of pesticides other than dieldrin were generally low and probably of negligible significance. Because oysters are extremely sensitive to organochlorine pollutants, these levels indicate little contamination of the waterways (*4*).

Dieldrin levels were higher and indicated a serious level of contamination of the Tamar River. Levels are comparable to those reported by Clegg for the Sydney rock oyster (*C. commercialis*) in the Brisbane River (*6*). Butler, reporting on the U.S. National Pesticide Monitoring Program (NPMP), noted similar levels of dieldrin in oysters from a few locations in Georgia, New York, South Carolina, and Washington, but these were the exception (*5*). Dieldrin was detected in only 15 percent of all NPMP samples.

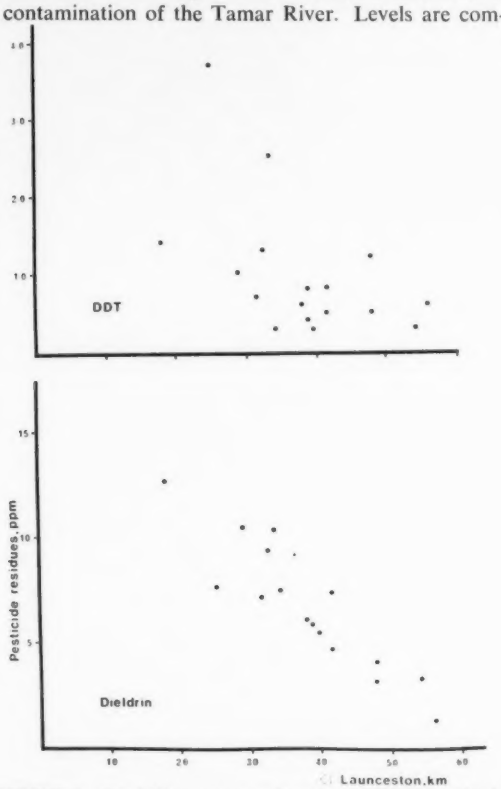


FIGURE 2. *Pesticide concentrations in oyster fats with increasing distance from Launceston, from sampling stations in Tamar River, Tasmania, Australia—March 1973*

Uptake of dieldrin by eastern oysters (*C. virginica*) was studied for a short term by Mason and Rowe (*11*) and over a longer period by Parrish (*14*). Concentration ratios for the pesticide were $2–8 \times 10^3$ for oysters exposed to ambient water concentrations of 0.1–9 μg/liter. If similar concentration factors apply to *C. gigas*, dieldrin levels in the Tamar River should range from 0.3 μg/liter to 0.075 μg/liter. This agrees with 0.18–0.02 μg/liter reported in a 1972–73 survey of the Tamar River by the State Department of the Environment (*8*).

Such levels would not affect embryonic development or larval growth and survival if Pacific oysters exhibit tolerances similar to those reported for eastern oysters. In the latter, Davis and Hidu (*7*) found little difference between controls and experimental cultures at dieldrin concentrations of 25 μg/liter.

Levels of DDT, HCB, and lindane in these oysters are within Australian tolerance standards for food (*13*) and represent little risk to public health. At present there is no published tolerance for dieldrin residues in fish, but if limits of the Food and Drug Administration, U.S. Department of Health, Education and Welfare, are applied (0.3 mg/kg, shellfish meats), then only one sample in the February survey exceeded these limits.

Results of the heavy-metal investigation mentioned earlier revealed widespread contamination of oysters in the Tamar River. Subsequently, oysters cannot be taken for human consumption from any point upstream of Point Rapid. This effectively removes any risk of consumption of oysters with high dieldrin concentrations because those downstream of Point Rapid exhibited much lower concentrations of the residue than did upstream samples. Distribution of pesticide levels throughout the Tamar River suggested that the minute amounts of DDT are probably attributable to agricultural runoff. Dieldrin levels suggested an upstream source of contamination for the pollutant. Industrial sources in Launceston were implicated in the Annual Report of the Department of the Environment (*8*), and it seems likely that the dieldrin was used to insect-proof woolen fabrics produced by a woolen mill in Launceston. Similar instances were recorded about mills in the United States (*10, 12*). Since this survey was conducted, the State Department of the Environment has attempted to limit the disposal of a number of pesticides in effluents. (The Launceston-

based woolen mill was prosecuted for illegal discharge of dieldrin residues.) Continued monitoring of Tamar River water samples for dieldrin and DDT has reflected the success of these moves. In 1972–73, dieldrin was detected in 89 percent of samples with a maximum concentration of 0.39 μg/liter; DDT was found in 14 percent of samples with a high of 0.04 μg/liter. Comparable figures for 1975–76 were: dieldrin, 70 percent, 0.13 μg/liter; DDT, 5 percent, trace (0.01 μg/liter) (B. O. Healey, Water Pollution Officer, Department of the Environment, Hobart, Tasmania. 1977. Unpublished data.)

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# FOOD AND FEED

## *DDT Residues in Butter and Infant Formula in India, 1977*[1]

G. S. Dhaliwal[2] and R. L. Kalra[2]

ABSTRACT

*Samples of commercial brands of butter and infant formula from different parts of India were examined for DDT residues. All 18 samples of butter representing nine brands were contaminated. Levels of DDT residues ranged from 0.42 to 11.36 ppm and exceeded the Food and Agriculture Organization/World Health Organization practical residue limit of 1.25 ppm in 90 percent of the samples. All four brands of infant formula contained DDT residues above the practical residue limit. Most DDT residues were in the form of p,p'-TDE in both commodities. This contamination of milk with excessive amounts of DDT residues seems to be widespread in India.*

### *Introduction*

The proportions of DDT and its metabolites present in cows' milk indicate possible sources of these residues (*5*). Different routes of animal exposure result in secretion of DDT in different forms (*11*). Animal uptake by aspiration or intravenous injection results in secretions of DDT; ingestion leads to secretions in the form of DDT metabolites.

Limited information is available in India on the nature of DDT residues in bovine milk. Milk samples from Delhi contained only residues of *p,p'*-DDT (*1*). On the other hand, most DDT residues in milk from Ludhiana were in the form of *p,p'*-TDE (*2*). Because milk is an important food commodity, particularly for children, it is necessary to know the extent and sources of its contamination with DDT. Samples of commercial brands of butter and infant formula from different parts of India were analyzed for DDT residues. These commodities were chosen because of their availability.

[1] Study financed in part by the Agricultural Research Service, U.S. Department of Agriculture, under PL 480 project "Studies on pesticides residues and monitoring of pesticidal pollution (IN-ARS-65)."

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### *Materials and Methods*

BUTTER

Different commercial brands of butter manufactured in Punjab, Haryana, Delhi, Rajasthan, and Gujarat were purchased from the local market in 100-g packages February and March 1977. Three butter samples weighing 100 g each were also purchased during the same period from local dairies situated in different parts of Ludhiana city. Laboratory extractions were made within 2 days.

The method described by Faubert Maunder et al. (*4*) was modified slightly and used to extract and isolate DDT residues. The butter was warmed at about 50°C to separate the fat which was decanted through dry filter paper. A 5-g sample of the clarified fat was dissolved in 10 ml of hexane and transferred quantitatively to a 125-ml separatory funnel by using additional small portions of hexane totaling 15 ml. The hexane extract was partitioned three times into hexane-saturated dimethylformamide, using 10 ml of solvent each time. The dimethylformamide fraction was backwashed with 10 ml of dimethylformamide-saturated hexane, diluted with 250 ml of water and 50 ml of sodium chloride-saturated aqueous solution, and extracted twice with 100 ml of hexane. The combined herane extracts were concentrated to about 5–10 ml for subsequent column cleanup. Silica gel, 60–200 mesh, was thoroughly washed with acetone and methanol and activated 1 hour at 130°C. It was packed in a 50-cm × 2-cm glass column to a height of 10 cm between layers of anhydrous sodium sulfate. The column was prewashed with 100 ml of hexane. The sample extract in hexane was added to the column and eluted with 150 ml of 50 percent benzene in hexane. The eluate was concentrated to 1–10 ml and was analyzed by thin-layer and gas-liquid chromatography.

Thin-layer chromatography was done by the method of Thompson et al. (*7*) on $AgNO_3$-incorporated, alumina-

G-coated glass plates. *n*-Hexane was used as the developing solvent. The *Rf* values were: *p,p'*-DDT, 0.65; *p,p'*-DDE, 0.88; *p,p'*-TDE, 0.35; *o,p'*-DDT, 0.77; *o,p'*-TDE, 0.42; α-BHC, 0.52; β-BHC, 0.1; γ-BHC, 0.32; and δ-BHC, 0.1.

GLC determinations were made by injecting 1–10 μl of the sample solution into a Model 7624 Packard gas chromatograph. Two columns were used: (A) was the working column and (B) was used for confirmation. Instrument parameters and operating conditions follow:

| | | |
|---|---|---|
| Detector: | Tritium electron-affinity | |
| Columns: | (A) | Pyrex, 102 cm long × 0.4 cm ID, packed with 5 percent DC-200 on 80–100-mesh Gas-Chrom Q |
| | (B) | Pyrex, 1.84 m long × 0.4 cm ID, packed with 2 percent DEGS on 80–100-mesh Gas-Chrom Q |
| Temperature: | Column | 190°C |
| | Detector | 200°C |
| | Inlet | 210°C |
| Carrier gas: | Nitrogen | |
| Flow rate: | 70 ml/minute for Column A<br>100 ml/minute for Column B | |

Retention times, in minutes, are listed below:

| | Column A | Column B |
|---|---|---|
| *p,p'*–DDE | 2 | 3.5 |
| *p,p'*–TDE | 2.5 | 10 |
| *p,p'*–DDT | 3 | 8 |
| *o,p'*–DDT | 2.5 | 5 |
| *o,p'*–TDE | 2 | 6.5 |
| α–BHC | 1 | 1.5 |
| γ–BHC | 1.10 | 2 |
| β–BHC | 1 | 5.5 |

On column A, the half-scale deflection was obtained with 0.5 ng of *p,p'*-DDE, 0.8 ng of *p,p'*-TDE, and 1.0 ng of *p,p'*-DDT. Quantitative estimations were made by comparing peak heights of the unknown with the standards treated similarly. Recoveries of DDT and its metabolites at the fortification levels of 0.5 ppm were 80–90 percent. Results were expressed as such and were not corrected for recovery. The limit of detection of *p,p'*-DDT in butter was 0.01 ppm.

The nature of DDT residues was confirmed by a micro-alkali dehydrohalogenation procedure in the *Manual of Analytical Methods for Analysis of Pesticide Residues in Human and Environmental Samples* (*10*).

INFANT FORMULA

Four brands of infant formula manufactured in Punjab, Bombay, and Gujarat were purchased from a local market in 500-g packages February-April 1977. Ten g of infant formula was weighed and diluted to 80 ml with distilled water. Each sample was blended with 160 ml of acetone and 160 ml of hexane in a vortex beaker for 3 minutes. The extract was centrifuged at 3000 rpm for 10 minutes. The hexane layer was removed by pipet, concentrated to about 25 ml, and partitioned into dimethylformamide three times, using 15 ml of solvent each time. The combined dimethylformamide fractions were cleaned and analyzed by the procedures described for butter.

### *Results and Discussion*

DDT residues in butter occurred mainly in the form of *p,p'*-DDT, *p,p'*-DDE, and *p,p'*-TDE. Small amounts of *o,p'*-DDT and *o,p'*-TDE were also detected. Some samples had BHC residues in the form of α-, β-, and γ-isomers. Only traces of BHC were found. The maximum residue, 1 ppm BHC, was found in a sample of butter from Gujarat.

Levels of DDT residues in eighteen samples of butter representing six commercial and three local brands are given in Table 1. All but one brand of butter contained DDT residues higher than the practical residue limit of 1.25 ppm established by the United Nations Food and Agriculture Organization (FAO)/World Health Organization (WHO) (*9*). The level of DDT residues varied from 0.42 to 11.36 ppm with an average of 4.77 ppm. In a study at Uttar Pradesh Agricultural University, Pantnager, India (*8*), two of five butter samples were contaminated with DDT at an average level of 0.4 ± 0.14 ppm. The highest level of DDT detected was 0.5 ppm. Agnihotri et al. (*1*) reported that seven of eight samples of butter collected from Delhi contained DDT residues higher than the practical residue limit. The concentration of residues varied from 1.1 to 8.0 ppm with an average level of 3.8 ppm. The present study shows that most of the commercial brands of butter manufactured in Punjab, Haryana, Delhi, Rajasthan, and Gujarat contained DDT residues higher than the practical residue limit, and suggests widespread contamination in India of milk with high levels of DDT residues.

TABLE 1. *Residues of DDT and its metabolites in commercial butter samples, India, 1977*

| Butter | Sample Number | Origin | Residues, ppm | | | |
|---|---|---|---|---|---|---|
| | | | DDT | DDE | TDE | ΣDDT |
| Brand I | 1 | Gujarat | 1.88 | 1.48 | 8.00 | 11.36 |
| | 2 | | 2.54 | 1.44 | 6.53 | 10.51 |
| | 3 | | 1.62 | 1.44 | 6.35 | 9.41 |
| Brand II | 1 | Haryana | 1.16 | 0.74 | 3.74 | 5.64 |
| | 2 | | 1.18 | 0.73 | 3.51 | 5.42 |
| | 3 | | 0.50 | 0.30 | 1.36 | 2.16 |
| Brand III | 1 | Punjab | 0.75 | 0.58 | 3.54 | 4.87 |
| | 2 | | 0.73 | 0.42 | 3.25 | 4.40 |
| | 3 | | 0.63 | 0.41 | 2.53 | 3.57 |
| Brand IV | 1 | Rajasthan | 0.75 | 0.73 | 3.73 | 5.21 |
| | 2 | | 0.68 | 0.49 | 2.63 | 3.80 |
| | 3 | | 0.70 | 0.42 | 2.50 | 3.62 |
| Brand V | 1 | Delhi | 0.35 | 0.25 | 1.55 | 2.15 |
| Brand VI | 1 | Gujarat | 0.02 | 0.17 | 0.33 | 0.52 |
| | 2 | | 0.02 | 0.19 | 0.21 | 0.42 |
| Locale I | 1 | Ludhiana | 0.81 | 0.58 | 4.47 | 5.86 |
| Locale II | 1 | Ludhiana | 0.70 | 0.42 | 2.84 | 3.96 |
| Locale III | 1 | Ludhiana | 0.57 | 0.38 | 2.16 | 3.11 |

TDE is the predominant metabolite detected in all brands of butter (Table 1). Milk collected recently from Ludhiana and surrounding areas showed similar results (*2*). Since TDE is not being used in India for crop protection or mosquito control, then TDE residues must arise as a result of metabolism of DDT. However, milk and butter samples from Delhi did not show residues of any metabolite. The residues were detected as DDT only (*1*). The other two studies carried out in India on the DDT contamination of milk and milk products did not consider the metabolites (*6, 8*). The high level of TDE found in butter samples suggests that cattle ingest DDT mainly through contaminated feed. Witt et al. found a 1:1 relation between levels of DDT residues in cattle feed and the concentration of DDT secreted in bovine milkfat (*12*). If this relationship were true in the present study, DDT residues in cattle feed would be expected to vary between 0.42 and 11.36 ppm, averaging 4.77 ppm. The sources of such high DDT contamination of cattle feed must be determined particularly because the use of DDT for plant protection is limited in India. DDT is used mainly for malaria control; indoor residual spraying on the walls and roofs is carried out at the rate of 1 g/m$^2$. Dhaliwal and Kalra suggested that the indoor spraying might contaminate stored feed, and thereby contribute partly toward the ingestion of DDT by cattle (*2*). However, the contribution of this and other sources of contamination of milk needs further investigation.

All four popular brands of infant formula contained DDT residues above the tolerance level of 1.25 ppm, usually in the form of TDE (Table 2). The concentration of DDT varied from 1.52 to 2.72 ppm, averaging 1.90 ppm. Apparently, no other study has been carried out in India on the DDT contamination of commercial infant formula. The present study shows that even the spray drying process in the manufacture of infant formula, does not reduce residues of DDT to below the FAO/WHO tolerance level. This corresponds with the observation of Engst et al. (*3*).

The average level of DDT residues found in infant formula is 1.90 ppm. The consumption of this milk by a three-month-old child weighing approximately 5 kg at the normal feeding rate of 135 g/day would result in a daily intake of 47 $\mu$g of DDT. This value is about twice the acceptable daily intake of 0.005 mg/kg of baby weight (25 $\mu$g for an infant weighing 5 kg) established for DDT by the Joint Pesticides Committee of FAO and WHO (*9*).

TABLE 2. *Residues of DDT and its metabolites in commercial infant formula samples, India, 1977*

| Infant Formula | Origin | Fat Content, % | Residues on Fat Basis, ppm | | | |
|---|---|---|---|---|---|---|
| | | | DDT | DDE | TDE | ΣDDT |
| Brand I | Punjab | 19 | 0.63 | 0.33 | 1.76 | 2.72 |
| Brand II | Bombay | 19 | 0.40 | 0.25 | 1.04 | 1.69 |
| Brand III | Gujarat | 18 | 0.26 | 0.36 | 1.03 | 1.65 |
| Brand IV | Bombay | 18 | 0.33 | 0.17 | 1.02 | 1.52 |

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# GENERAL

## *Organochlorine Pesticides and Polychlorinated Biphenyls on Sediments from a Subarctic Salt Marsh, James Bay, Canada—1976*

W. A. Glooschenko[1] and R. C. J. Sampson[2]

ABSTRACT

*Sediment samples were collected from a subarctic salt marsh on James Bay, Ontario in May 1976. Of 15 organochlorine compounds analyzed, trace amounts mainly of p,p′-DDE and polychlorinated biphenyls (PCBs) were detected, but could not be quantitated.*

### *Introduction*

Organochlorine pesticides and polychlorinated biphenyls (PCBs) have been detected in subarctic and arctic marine food chains. PCBs and ΣDDT have been found in polar bears, seals, and fish in the Canadian arctic (*1*) and in fish in a landlocked lake in northwestern Quebec (*5*). The authors wished to determine levels of these organochlorine compounds in sediments of a subarctic wetland since this part of the ecosystem would be the ultimate sink of many of the compounds.

Sediment samples were collected in May 1976 from a subarctic salt marsh at North Point, Ontario (51°29′N, 80°27′W), on the western shore of James Bay, approximately 27 km northeast of Moosonee at the southern end of James Bay. A sample was collected in Moosonee from a drainage ditch to check the possibility of local sources of contamination.

### *Methods and Materials*

Sediment samples were collected by hand with a stainless steel trowel from the top 5 cm of five salt marsh sites, two freshwater creek sediments, and a drainage ditch in the Moosonee settlement. Samples were placed in aluminum cans which had been carefully cleaned with interference-free solvents and were frozen until analysis within two months of collection.

Thawed wet-sediment samples (10 g) were extracted by using an ultrasonic probe. Each sample was extracted three times with 75 ml of acetonitrile for 2 minutes each time and filtered through Celite and sodium sulfate. The combined filtrate and washings were partitioned into petroleum ether, washed with water, dried with sodium sulfate, and evaporated with a rotary evaporator to 1 ml, using isooctane as a keeper. Recovery was 80–100 percent (*2*).

The concentrate was analyzed by high-pressure liquid chromatography. Four fractions were collected, evaporated to 1 ml, and analyzed by computerized gas chromatography (GC) with automatic sampling. Identification was based on quantitative reproducibility (±20 percent) on four columns of varying polarity with a 2 percent retention time variability window. Instrument parameters and operating conditions follow.

| | |
|---|---|
| Detectors: | linearized $^{63}$Ni electron-capture |
| Columns: | (1) 2 m × 3.5 mm I.D., pyrex, packed with mixture of 1.5 percent OV-17 and 1.95 percent QF-1 on 100–120-mesh Gas-Chrom Q<br>(2) 1.86 m × 4 mm I.D., packed with mixture of 4 percent OV-101 and 6 percent OV-210 or QF-1 on 80–100-mesh Gas-Chrom Q<br>(3) 1.86 × 4 mm I.D., packed with 3 percent OV-101 on 80–100-mesh Chromosorb W-HP<br>(4) 2 m × 3.5 mm I.D., packed with 3 percent OV-225 on 100–120-mesh Gas-Chrom Q |
| Temperatures: | column 200° C<br>injector 225° C<br>detector 325° C |
| Carrier gases: | mixture of 5 percent methane and 95 percent argon flowing at 50–75 ml/minute |

Quantitation limits are given in Table 1. Detection limits for the pesticides analyzed are approximately one-tenth the quantitation limit. Authors were unable to confirm identities of residues by mass spectrometry because of the low levels of compounds.

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TABLE 1. *Distribution of organochlorines in sediments from North Point salt marsh complex*

| Compound | Quantitation Limit, μG/G | Sample Site: Salt Marsh 1 | Salt Marsh 2 | Salt Marsh 3 | Salt Marsh 4 | Salt Marsh 5 | Creek Beds 1 | Creek Beds 2 | Moosonee 1 |
|---|---|---|---|---|---|---|---|---|---|
| | | Residues, μG/G dry weight | | | | | | | |
| Lindane | 0.001 | < 0.001 | ND | ND | ND | ND | ND | ND | < 0.001 |
| Heptachlor | 0.001 | ND | ND | ND | ND | ND | ND | ND | ND |
| Aldrin | 0.001 | ND | ND | ND | ND | ND | ND | ND | ND |
| Heptachlor epoxide | 0.001 | ND | ND | ND | ND | ND | ND | ND | ND |
| *p,p'*-DDE | 0.001 | < 0.001 | < 0.001 | ND | < 0.001 | < 0.001 | < 0.001 | < 0.001 | < 0.001 |
| Dieldrin | 0.001 | ND | ND | ND | ND | ND | ND | ND | ND |
| *p,p'*-DDT | 0.001 | ND | ND | ND | ND | < 0.001 | ND | ND | ND |
| *o,p'*-DDT | 0.001 | ND | ND | ND | ND | ND | ND | ND | ND |
| Endrin | 0.001 | ND | ND | ND | < 0.001 | ND | ND | ND | ND |
| α-Chlordane | 0.005 | ND | ND | ND | ND | ND | ND | ND | ND |
| γ-Chlordane | 0.005 | ND | ND | ND | ND | ND | ND | ND | ND |
| α-Endosulfan | 0.01 | ND | ND | ND | ND | ND | ND | ND | ND |
| β-Endosulfan | 0.01 | ND | ND | ND | ND | ND | ND | < 0.01 | ND |
| *p-p'*-Methoxychlor | 0.05 | ND | ND | ND | ND | ND | ND | ND | < 0.05 |
| Total PCBs | 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 | < 0.1 |

## *Results and Discussion*

Results are in Table 1. Of the 15 organochlorine compounds, none could be quantitated. However, *p,p'*-DDE and PCBs were detected in nearly all the samples. Traces of lindane, *p,p'*-DDT, endrin β-endosulfan, and *p,p'*-methoxychlor were noted.

No river entering James Bay drains regions of agriculture, nor is there intensive recreational use of the area, a source of pesticide input in southern Ontario (*2–4*). Therefore, it appears that traces of organochlorine compounds have been transported to the area by air.

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# APPENDIX

## *Chemical Names of Compounds Discussed in This Issue*

| | |
|---|---|
| ALDRIN | Hexachlorohexahydro-*endo, exo*-dimethanonaphthalene 95% and related compounds 5% |
| AROCLOR 1242 | PCB, approximately 42% chlorine |
| AROCLOR 1254 | PCB, approximately 54% chlorine |
| AROCLOR 1260 | PCB, approximately 60% chlorine |
| AZINPHOSMETHYL | *O,O*-Dimethyl *S*-[(4-oxo-1,2,3-benzotriazin-3(4*H*)-yl)methyl] phosphorodithioate |
| BENZENE HEXACHLORIDE (BHC) | 1,2,3,4,5,6-Hexachlorocyclohexane |
| BROMACIL | 5-Bromo-3-*sec*-butyl-6-methyluracil |
| CARBOPHENOTHION | *S*-[[(*p*-Chlorophenyl)thio]methyl] *O,O*-diethyl phosphorodithioate |
| CHLORDANE | Octachloro-4,7-methanotetrahydroindane 60% and related compounds 40% |
| DDE | Dichlorodiphenyldichloroethylene |
| DDT | Dichorodiphenyltrichloroethylene |
| DACTHAL (DCPA) | Dimethyl tetrachloroterephthalate |
| DEF | *S,S,S*-Tributyl phosphorotrithioate |
| DEMETON | *O,O*-Diethyl *O*-[2-(ethylthio)ethyl] phosphorothioate and *O,O*-diethyl *S*-[2-(ethylthio)ethyl] phosphorothioate |
| DIAZINON | *O,O*-Diethyl *O*-(2-isopropyl-6-methyl-4-pyrimidinyl) phosphorothioate |
| DIELDRIN | Hexachloroepoxyoctahydro-*endo, exo*-dimethanonaphthalene 85% and related compounds 15% |
| DIURON | 3-(3,4-Dichlorophenyl)-1,1-dimethylurea |
| ENDOSULFAN | Hexachlorohexahydromethano-2,4,3-benzodioxathiepin-3-oxide |
| ENDRIN | Hexachloroepoxyoctahydro-*endo, endo*-dimethanonaphthalene |
| ETHION | *O,O,O',O'*-Tetraethyl *S,S'*-methylene bisphosphorodithioate |
| HEPTACHLOR | Heptachlorotetrahydro-4,7-methanoindene and related compounds |
| LINDANE | *Gamma* isomer of 1,2,3,4,5,6-hexachlorocyclohexane |
| MALATHION | *O,O*-Dimethyl dithiophosphate of diethyl mercaptosuccinate |
| METHOXYCHLOR | 2,2-Bis(*p*-methoxyphenyl)-1,1,1-trichloroethane 88% and related compounds 12% |
| MIREX | Dodecachlorooctahydro-1,3-methano-1*H*-cyclobuta[cd]pentalene |
| PARATHION | *O,O*-Diethyl *O*-*p*-nitrophenyl phosphorothioate |
| PHORATE | *O,O*-Diethyl *S*-[(ethylthio)methyl] phosphorodithioate |
| PCBs | Polychlorinated biphenlys, mixtures of chlorinated biphenyl compounds having various percentages of chlorine |
| TDE | Dichlorodiphenyldichloroethane |
| TOXAPHENE | Technical chlorinated camphene 67-69% chlorine |
| TRIFLURALIN | $\alpha,\alpha,\alpha$-Trifluoro-2,6-dinitro-*N,N*-dipropyl *p*-toluidine |

## *Information for Contributors*

The *Pesticides Monitoring Journal* welcomes from all sources qualified data and interpretative information on pesticide monitoring. The publication is distributed principally to scientists, technicians, and administrators associated with pesticide monitoring, research, and other programs concerned with pesticides in the environment. Other subscribers work in agriculture, chemical manufacturing, food processing, medicine, public health, and conservation.

Articles are grouped under seven headings. Five follow the basic environmental components of the National Pesticide Monitoring Program: Pesticide Residues in People; Pesticide Residues in Water; Pesticide Residues in Soil; Pesticide Residues in Food and Feed; and Pesticide Residues in Fish, Wildlife, and Estuaries. The sixth is a general heading; the seventh encompasses briefs.

Monitoring is defined here as the repeated sampling and analysis of environmental components to obtain reliable estimates of levels of pesticide residues and related compounds in these components and the changes in these levels with time. It can include the recording of residues at a given time and place, or the comparison of residues in different geographic areas. The Journal will publish results of such investigations and data on levels of pesticide residues in all portions of the environment in sufficient detail to permit interpretations and conclusions by author and reader alike. Such investigations should be specifically designed and planned for monitoring purposes. The Journal does not generally publish original research investigations on subjects such as pesticide analytical methods, pesticide metabolism, or field trials (studies in which pesticides are experimentally applied to a plot or field and pesticide residue depletion rates and movement within the treated plot or field are observed).

Authors are responsible for the accuracy and validity of their data and interpretations, including tables, charts, and references. Pesticides ordinarily should be identified by common or generic names approved by national or international scientific societies. Trade names are acceptable for compounds which have no common names. Structural chemical formulas should be used when appropriate. Accuracy, reliability, and limitations of sampling and analytical methods employed must be described thoroughly, indicating procedures and controls used, such as recovery experiments at appropriate levels, confirmatory tests, and application of internal standards and interlaboratory checks. The procedure employed should be described in detail. If reference is made to procedures in another paper, crucial points or modifications should be noted. Sensitivity of the method and limits of detection should be given, particularly when very low levels of pesticide residues are being reported. Specific note should be made regarding correction of data for percent recoveries. Numerical data, plot dimensions, and instrument measurements should be reported in metric units.

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